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ASTRONOMICAL

AND

GEOGRAPHICAL

ESSAYS:

CONTAINING,

I.

A FULL AND COMPREHENSIVE VIEW, ON A NEW PLAN,

OF THE

General Principles of Aſtronomy.

II.

THE USE OF THE

CELESTIAL AND TERRESTRIAL GLOBES,

Exemplified in a greater Variety of PROBLEMS, than are to be found in any other Work; they are arranged under diſtinct Heads, and interſperſed with much curious, but relative Information.

III.

THE DESCRIPTION AND USE OF THE

ARMILLARY SPHERE, PLANETARIUM, TELLURIAN, AND LUNARIUM.

IV.

AN INTRODUCTION TO

PRACTICAL ASTRONOMY;

Or, the USE of the QUADRANT and EQUATORIAL.

SECOND EDITION.

By GEORGE ADAMS,

MATHEMATICAL-INSTRUMENT MAKER TO HIS MAJESTY, AND OPTICIAN TO HIS ROYAL HIGHNESS THE PRINCE OF WALES.

LONDON:

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M.DCC.XC.

P R E F A C E.

THE connection of aſtronomy with geography is ſo evident, and both in conjunction ſo neceſſary to a liberal education, that no man will be thought to have deſerved ill of the republic of letters, who has applied his endeavours to diffuſe more univerſally the knowledge of theſe uſeful ſciences, or to render the attainment of them eaſier; for as no branch of literature can be fully comprehended without them, ſo there is none which impreſs more pleaſing ideas on the mind, or that afford it a more rational entertainment.

The fifth edition of my father's treatiſe on the globes being out of print, I was ſolicited to reprint it. To obviate ſeveral objections to the form in which he had diſpoſed the problems, I was induced to undertake the preſent work, in which they are arranged in a more methodical manner, and a great number added to them. Such facts are alſo occaſionally introduced, ſuch obſervations interſperſed, and ſuch relative information communicated, as it is preſumed will excite curioſity, and fix attention.

Having proceeded ſo far in this work, I found that it was eaſy to render it ſubſervient to

my plan of publiſhing, from time to time, "ESSAYS, DESCRIBING THE USE OF MATHEMATICAL AND PHILOSOPHICAL INSTRUMENTS:" for the deſcription of thoſe which have been contrived to ſmooth the path to the ſcience of aſtronomy, or to facilitate the practice of the arts depending on it, could no where be introduced with ſo much propriety, as in a work which treated of it's elementary principles.

To further this deſign, it was neceſſary to prefix an introduction to aſtronomy. This is divided into three parts. In the firſt, the pupil is ſuppoſed to be placed in the ſun, the center of the ſolar ſyſtem; from this ſituation he conſiders the motion of the heavenly hoſt, and finds that all is regular and harmonious. In the ſecond part, his attention is directed to the appearances of the planetary bodies, as obſerved from the earth. It were to be wiſhed that the tutor would at this part exhibit to his pupil the various phænomena in the heavens themſelves; by teaching him thus to obſerve for himſelf, he would not only raiſe his curioſity, but ſo fix the impreſſions which the objects have made on his mind, that by proper cultivation they would prove a fruitful ſource of uſeful employment; and he would thereby alſo gratify that eager deſire after novelty, which continually animates young minds, and furniſh them with objects on which to exerciſe their natural activity. In the third part of this intro-

troduction, the received, or Copernican ſyſtem is explained; by this ſyſtem, the various phænomena of the heavens are rationally accounted for; it ſhews us how to reconcile the real ſtate of things, with the fallacies ariſing from the ſenſes; and teaches us that the irregularities obſervable in the motion of the heavenly bodies, are for the moſt part to be attributed to the ſituation from which they are obſerved. Aſtronomy, in common with other branches of the mathematics, while it ſtrengthens the powers of the mind, reſtrains it from raſh preſumption, and diſpoſes it to a rational aſſent.

The principles of the Copernican ſyſtem are further elucidated in the third eſſay; in which, various planetariums, lunariums, and tellurians, are deſcribed. Theſe inſtruments, though leſs complicated in their conſtruction, and leſs expenſive to the purchaſer, than thoſe large ones heretofore made for the ſame purpoſe, are equally, perhaps better, adapted to explain the general principles of aſtronomy. In deſcribing them, it was neceſſary to re-conſider many ſubjects which had been previouſly treated; but as they are here placed in another point of view, preſented to the mind under a different form, are generally deſcribed in other words, and often with the addition of new matter, it is hoped that theſe repetitions, ſo far from being an object of complaint, will be found to contribute to the main

intention of this work, by conveying further inſtruction, fixing it more deeply in the mind, and rendering that obvious, which before might be found difficult.

One part ſtill ſeemed wanting to an introductory treatiſe on aſtronomy, ſomething that would gently lead the pupil to a knowledge of the practical part of this ſcience, a branch of aſtronomy to which we are indebted for our preſent knowledge of the heavens, by which geography has been improved, and by which the paſſage of ſhips over the trackleſs ocean is facilitated.

There is no part of mathematical ſcience more ſimple and eaſy, than the meaſurement of the relative poſitions and diſtances of inacceſſible objects. Yet to the uninſtructed, to determine the diſtance of a ſhip on the ocean, to aſcertain the height of the clouds and meteors that float in the atmoſphere, to fix the latitude and longitude of places, &c. are problems that have ever appeared to be above the reach of human art; they are, therefore, particularly calculated to engage the attention of young minds, and may be uſed to encourage diligence, and reward application.

To introduce the pupil to this branch of aſtronomy, I have deſcribed three inſtruments, each of which is ſimple in it's conſtruction; and two of them of ſmall expence. By theſe he may find the diſtance of any inacceſſible object, the

height of a ſpire, a mountain, or any other elevation, learn to plot a field, aſcertain the altitude of a cloud, a fire-ball, or any other meteor, determine with accuracy the hour of the day, the latitude or longitude of a place, with many other curious problems. In the ſelection of theſe, I have to acknowledge the aſſiſtance I received from a very ingenious friend.

I had intended to ſubjoin to this preface a liſt of aſtronomical authors, that the reader might know as well where to apply for further information, as the ſources from whence I obtained my knowledge of this ſubject. But the work has ſwelled ſo much beyond my expectations, that I am conſtrained to lay aſide this deſign.

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ASTRONOMICAL ESSAYS.

ESSAY I.

PART I.

MANKIND have in all ages been deſirous of forming rational conceptions of the nature and motion of thoſe bodies that appear in the vaſt concave above their heads. Amidſt the infinite variety of objects which ſurround them on every ſide, the heavenly bodies muſt have been amongſt thoſe which firſt attracted their attention. They are of all objects the moſt conſpicuous, the moſt important, and the moſt beautiful.

Aſtronomy inſtructs us in the laws, or rules, that govern and direct the motions of the heavenly hoſt. It weighs and conſiders the powers by which they circulate in their orbs. It enables us to diſcover their ſize, determine their

diſtance, explain their various phænomena, and correct the fallacies of the ſenſes by the light of truth.

Aſtronomy is not merely a ſpeculative ſcience; it's uſe is as extenſive, as it's reſearches are ſublime. Navigation owns it for it's guide: by it commerce has been extended, and geography improved; and thus it has co-operated with other cauſes in the greateſt of all works, the diffuſion of knowledge, and the civilization of man.

As in order to attain an accurate idea of any piece of mechaniſm, it is beſt to begin our inveſtigations by an examination of thoſe parts which give motion to the reſt, the primary cauſes of thoſe effects for which the machine was made; ſo the young pupil will more eaſily gain a juſt idea of the motion of the heavenly bodies, by conſidering them as ſeen from the ſun, the center of our ſyſtem, and the principal agent uſed by the LORD OF NATURE, for conducting and regulating the planetary ſyſtem.

It will not be difficult, after this, to inform him how thoſe appearances are to be accounted for, that ariſe from his particular ſituation; by which he is forced to conſider the heavens from a point which is not in the center of the ſyſtem, and is conſequently the ſource of many apparent irregularities. This knowledge attained, it will then be eaſy to prove to him, that the real and apparent

apparent motions of the heavenly bodies are frequently the reverfe of each other. For being by this means put into poffeffion of the univerfals of this fcience, the knowledge of particulars will be rendered facile and clear.

OF THE SOLAR SYSTEM, AS SEEN BY A SPECTATOR, SUPPOSED TO BE PLACED IN THE SUN.

As the center of the fyftem is the only place from which the motion of the planets can be truly feen, let us fuppofe AN OBSERVER placed in the center of the fun. In this fituation he will fee at one view all the heavens, which will appear to him perfectly fpherical, the ftars being fo many lucid points in the concave furface of the fphere whofe center is the fun; or, in the prefent inftance, the eye of the obferver.

Our fpectator will not, however, immediately conclude from appearances, either that the heavens are really fpherical, or that the fun is in the center of that fphere, or that the ftars are all at an equal diftance from him, having been previoufly taught by experience and obfervation, that while he remains in the fame place, he cannot judge properly of the diftance of furrounding objects, at leaft of thofe which are placed beyond the ordinary reach of his view; for beyond that diftance, all the principles by which we form our general judgment fail us; and we

can only tell which is neareſt, or which is furtheſt, either by our own motion, or that of the objects.

To illuſtrate this, let us ſuppoſe a number of lamps, to be placed irregularly, at different diſtances from the eye, in a dark night. Now if in this caſe we ſuppoſe the darkneſs to be ſo complete, that no intermediate objects could be ſeen, no difference in colour diſcerned, nor any perception of a convergence towards the point of ſight, our judgment could not aſſiſt us in diſtinguiſhing the diſtance of one from the other, and they would therefore all ſeem to be at an equal diſtance from the ſpectator.

For the ſame reaſon, the ſun and moon, the ſtars and planets, appear to be all at an equal diſtance from us; though it is highly probable, that ſome of the ſtars are many millions of times nearer to us than others. The ſun is demonſtrated to be nearer than any of the ſtars. The moon and ſome of the planets are known by ocular proof to be nearer to us than the ſun, becauſe they ſometimes come between it and our eye, and hide the whole, or a great part of his diſk, from our view. They all, however, appear equally diſtant, and as if placed in the ſurface of a ſphere, whereof our eye is the center. In whatever place, therefore, the ſpectator reſides, whether it be on this earth, in the ſun, or in the regions of Saturn, he will conſider that

that place as the middle point of the univerſe, and the center of the world; for it will be to him the center of a ſpherical ſurface, in which all diſtant bodies appear to be placed.

Here the tutor will find his advantage in illuſtrating this ſubject by actual experiments on real objects, and thus extending the ideas of his pupil. Young people ſhould be taught to gain as much information as poſſible from ſenſible images; by theſe their mind would be gradually led to feel it's powers, and ſoon learn to correct thoſe errors which are induced into it by appearances, derived only from the ſenſes. No man can at once convey light in the higher ſubjects to another man's underſtanding. It muſt come into the mind from it's own motions, within itſelf; and the grand art of philoſophy and education, is to ſet the mind in action, and even when we think nothing of it, to aſſiſt it in it's labour.*

Theſe things being rendered plain, the pupil may proceed to conſider the obſervations of the ſolar ſpectator; to whom, as we have already obſerved, the heavens will appear as the ſurface of a concave ſphere, concentrical to his eye: in this ſurface he will diſcover an innumerable hoſt of fixed ſtars, which will for ſome time engage his attention, before he diſcovers that they may

* Petvin's Notes to Letters on Mind.

be diſtinguiſhed into two kinds; the one diſperſed through the whole heavens, differing in their degree of brightneſs, but remaining always at the ſame relative diſtance from each other. Theſe he will therefore call FIXED STARS, or only STARS. Beſides theſe, he will find ſome others moving among the foregoing with different velocities, which he will call WANDERING STARS, or PLANETS.

Here, however, it may be proper to obſerve, that what we call the ſky, in which the heavenly bodies ſeem as it were to be fixed, is no real ſubſtance. If there was no atmoſphere ſurrounding our earth, whoſe particles might reflect other rays of light to our eyes, than thoſe which come directly from the ſun, all parts of the heavens, even at mid-day, would be dark, and the ſtars be viſible at noon. But as our atmoſphere abounds with particles capable of reflecting light every way, ſome of it will fall upon our eyes whitherſoever they are directed; from the nature of this reflection, we receive the idea of colour, and the mind immediately imagines a ſubſtance wherein it may reſide; in the ſame manner, the regular reflection of light from an object in a looking glaſs, is combined by the mind into an image of that object. Mr. de Sauſſure, when on the top of Mount Blanc, in Savoy, a mountain which is elevated 15673 feet perpendicularly above the ſea, and where conſequently the atmo-

ſphere

ſphere muſt be much rarer than our's, ſays, that the moon ſhone with the brighteſt ſplendor in the midſt of a ſky as black as ebony; while Jupiter, rayed like the ſun, roſe from behind the mountains in the eaſt.*

OF THE CELESTIAL SIGNS AND CONSTELLATIONS.

Having proceeded thus far, our ſpectator will endeavour to find out ſome method of diſtinguiſhing the ſtars from each other; concluding, that as they do not change their relative poſitions one to the other, he may make an exact deſcription of them, and by repeated obſervations determine the poſition and order which ſubſiſts among them.

That he may avoid confuſion in deſcription, and be able to point out any particular ſtar, without being obliged to give a name to each, he will divide them into ſeveral parcels; to each of theſe parcels he will aſſign a figure at pleaſure; theſe aſſemblages, or groupes of ſtars, he will call CONSTELLATIONS. Thus a number of ſtars near the north pole is called the bear, becauſe the ſtars which compoſe it are at ſuch diſtances from each other, that they may fall within the figure of a bear. Another conſtellation is called the ſhip, becauſe that collection of ſtars which compoſe it, is repreſented upon a celeſtial globe

* Appendix to vol. 74, Monthly Review.

as comprized within ſome part of the figure of a ſhip.

The diviſion of the ſtars into conſtellations is of the higheſt antiquity; there are no books ſo ancient, in which the heavens are at all conſidered, but we find them treated of as diſtinguiſhed into conſtellations; Heſiod and Homer mention ſeveral by names that are now known, and we find Job ſpeaking of Orion and the Pleiades. It was not from ignorance that the moſt ancient people aſſigned them the names of men and beaſts; they had in many things, reaſons which are not common to us, and it was ſo in this; and thoſe who attend to the uſe and application of the images drawn from natural objects in the ſcriptures, will not find it difficult to decypher the hieroglyphic language of the heavens, and they will alſo find it a pleaſing ſource of rational entertainment.

As the fixed ſtars will appear to our obſerver of different degrees of magnitude and ſplendor, he will divide them into ſix different claſſes. Thoſe which ſeem the largeſt and brighteſt, he will call ſtars of the firſt magnitude; the ſmalleſt that we can ſee with the naked eye, are called ſtars of the ſixth magnitude; and the intermediate ones, according to their different apparent ſizes, he will call of the ſecond, third, fourth, or fifth magnitudes. Thoſe ſtars which cannot be ſeen without the aſſiſtance of a teleſcope, are not reckoned

reckoned in any of theſe claſſes, and are called TELESCOPIC STARS.

By a knowledge of the fixed ſtars and their poſitions, our obſerver will obtain ſo many fixed points, by which he may obſerve the motions of the planets; and the relation of theſe motions to each other, he will uſe them as ſo many land-marks (if the word may be allowed) by which the ſituations of other celeſtial bodies may be aſcertained, and the varieties to which they are ſubject be obſerved. For from the ſame place, the motions of the heavenly bodies can only be eſtimated by the angle formed at the ſpectator's eye by the ſpace which the moving body paſſes over.

To meaſure theſe ſpaces, the ſtars muſt be uſed, and conſidered as ſo many luminous points fixed in the concavity of a ſphere, whoſe radius is indefinite, and of which the obſerver's eye is the center. We may learn from hence the neceſſity of forming an exact catalogue of the ſtars, and of determining their poſitions with accuracy and care. With ſuch a catalogue, the ſcience of aſtronomy begins.

Although to thoſe who are unacquainted with the nature of celeſtial obſervation, it might at firſt ſight appear almoſt impoſſible to number the ſtars; yet their relative ſituations have been ſo carefully obſerved by aſtronomers, that they have not only been numbered, but even their places

in the heavens have been aſcertained with greater accuracy, than the relative ſituation of moſt places on the ſurface of the earth.

The greateſt number of ſtars that are viſible to the naked eye, are to be ſeen on a winter's night, when the air is clear, and no moon appears. But even then a good eye can ſcarce diſtinguiſh more than one thouſand at a time in the viſible hemiſphere: for though on ſuch a night they appear to be almoſt innumerable, this appearance is a deception, that ariſes from our viewing them in a tranſient and confuſed manner; whereas, if we view them diſtinctly, and only conſider a ſmall portion of the heavens at a time, and after ſome attention to the ſituation of the remarkable ſtars contained in that portion, begin to count, we ſhall be ſurprized at the ſmallneſs of their number, and the eaſe with which they may be enumerated.

Hipparchus, the Rhodian, about an hundred and twenty years before the birth of Chriſt, was the firſt among the Greeks who reduced the ſtars into a catalogue; daring, according to Pliny, "to undertake a thing, which ſeemed to ſurpaſs the power of a divinity; that is, to number the ſtars for poſterity, and to reduce them into order; having contrived inſtruments, by which he marked the place and magnitude of each ſtar. So that by theſe means we can eaſily diſcover, not only whether any of the ſtars periſh, and others

others grow up, but also whether they move, and if ſo, the direction of their motion, whether they increaſe or diminiſh; thus putting poſterity in poſſeſſion, as it were, of the heavens." His catalogue, firſt adopted by Ptolemy, contained only 1026 ſtars. Since that time the liſt has been conſiderably augmented, and is daily receiving freſh increaſe, by the improvement of teleſcopes.

Several aſtronomers have followed Hipparchus in the ſame arduous undertaking. In 1603, J. Bayer publiſhed celeſtial charts of all the known conſtellations, and of the viſible ſtars of which they are compoſed. In theſe charts every ſtar is diſtinguiſhed by a letter. The largeſt ſtar in the conſtellation is marked with the firſt letter of the Greek alphabet; the next in apparent ſize is marked with the ſecond letter, and ſo on. If there are more ſtars in the conſtellation than there are letters in the Greek alphabet, he marks the remainder with the letters of the Roman alphabet. When a ſtar is mentioned with the letters of the Greek or Roman alphabet, it is always with the additional name of the conſtellation to which it belongs; and thus to thoſe who are acquainted with the figures of the conſtellations, and with the catalogue of fixed ſtars, it becomes as determinate a denomination, as if the ſtar was called by a proper name, and the ſame purpoſe is anſwered

in

in a more familiar manner, and with leſs burthen upon the memory. Among the various catalogues, the moſt copious and as generally eſteemed the beſt, is that called Hiſtoria Cœleſtis, of our countryman, Flamſteed.

The number of the ancient conſtellations was 48; in theſe were included 1022 ſtars. Many conſtellations have been added by modern aſtronomers; ſo that the catalogues of Flamſteed and De la Caille, when added together, are found to contain near five thouſand ſtars. The names of the conſtellations, their ſituation in the heavens, with other particulars, are beſt learned by ſtudying the artificial repreſentation of the heavens, a celeſtial globe.

The galaxy or milky way muſt not be neglected; it is one of the moſt remarkable appearances in the heavens; it is a broad circle of a whitiſh hue, in ſome places it is double, but for the moſt part conſiſts of a ſingle path ſurrounding the whole celeſtial concave. The great Galileo diſcovered by the teleſcope, that the portion of the heavens which this circle paſſes through, was every where filled with an infinite multitude of exceeding ſmall ſtars, too ſmall to be diſcovered by the naked eye; but by the combination of their light diffuſing a ſhining whiteneſs through the heavens. Mr. Brydone ſays, that when he was at the top of Mount Etna, the milky way

had

had the moſt beautiful effect, appearing like a pure flame that ſhot acroſs the heavens.

This idea of the milky way, that it is formed of an innumerable cluſter of ſmall ſtars, is not, however, new; for among the various conjectures of Manilius, we find the following:

" Or is the ſpacious band ſerenely bright
From little ſtars, which there their beams unite,
And form one ſolid and continu'd light?"

The ſtars appear of a ſenſible magnitude to the naked eye, becauſe the retina is not only affected by the rays of light which are emitted directly from them, but by many thouſands more, which, falling upon our eye-laſhes, and upon the viſible aerial particles about us, are reflected into our eyes ſo ſtrongly, as to excite vibrations, not only in thoſe points of the retina, where the real images of the ſtars are formed, but alſo in other parts round about it. This makes us imagine the ſtars to be much bigger, than they would be if we ſaw them only by the few rays which come directly from them to our eyes, without being intermixed with others. Any one may be made ſenſible of this, by looking at a ſtar of the firſt magnitude, through a long narrow tube; which, though it takes in as much of the ſky as would hold a thouſand of ſuch ſtars, ſcarce renders that one viſible.

The number of the ſtars almoſt infinitely exceeds what we have yet been ſpeaking of. An ordinary

ordinary telefcope will difcover, in feveral parts of the heavens, ten times as many ftars as are vifible to the naked eye. Hooke, in his Micrographia, fays, that with a telefcope of twelve feet he difcovered feventy-eight ftars among the Pleiades, and with a more perfect telefcope, many more. Galileo reckoned eighty in the fpace between the belt and the fword of Orion, and above five hundred more in another part of the fame conftellation, within the compafs of one or two degrees fquare. Antonia Maria de Rheita counted in the fame conftellation above two thoufand ftars. Future improvements in telefcopes may enable us to difcover numberlefs ftars that are now invifible; and many more there may be, which are too remote to be feen through telefcopes, even when they have received their ultimate improvement. Dr. Herfchel, to whofe ingenuity and affiduity the aftronomical world is fo much indebted, and whofe enthufiaftic ardor has revived the fpirit of difcoveries, of which we fhall fpeak more largely in another part of this effay, has evinced what great difcoveries may be made by improvements in the inftruments of obfervation. In fpeaking here of his difcoveries, I fhall ufe the words of M. de la Lande.* "In paffing rapidly over the heavens with his new telefcope, the univerfe increafed under his eye;

44000

* Memoires de l'Academie de Dyon, 1785.

44000 ſtars, ſeen in the ſpace of a few degrees, ſeemed to indicate that there were ſeventy-five millions in the heavens." He has alſo ſhewn that many ſtars, which to the eye, or through ordinary glaſſes, appear ſingle, do in fact conſiſt of two or more ſtars. The galaxy or milky way owes it's light entirely to the multitude of ſmall ſtars, placed ſo cloſe as not to be diſcoverable, even by an ordinary teleſcope. The nebulæ, or ſmall whitiſh ſpecks, diſcerned by means of teleſcopes, owe their origin to the ſame cauſe; former aſtronomers could only reckon 103, Dr. Herſchel has diſcovered upwards of 1250 of theſe cluſters, beſides a ſpecies which he calls planetary nebulæ. But what are all theſe, when compared to thoſe that fill the whole expanſe, the boundleſs fields of ether! Indeed, the immenſity of the univerſe muſt contain ſuch numbers, as would exceed the utmoſt ſtretch of the human imagination. For who can ſay, how far the univerſe extends, or where are the limits of it? where the Creator ſtayed "his rapid wheels;" or where he "fixed the golden compaſſes?"

Of the Planets, as seen from the Sun.

Our ſolar obſerver having attained a competent knowledge of the fixed ſtars, will now apply himſelf to conſider the planets: theſe, as we have already obſerved, he will ſoon diſtinguiſh, by

by their motion, from the fixed ſtars; the ſtars always remaining in their places, but the planets will be ſeen paſſing by them with unequal velocities. Thus on obſerving the earth, for inſtance, he will find it moving among the fixed ſtars, and approaching nearer and nearer to the more eaſtern ones; in a year's time it will complete it's revolution, and return to the ſame place again.

He will find ſeven of theſe bodies revolving round the ſun, to each of which he will aſſign a name, calling the ſwifteſt MERCURY, denominating the others in order, according to their velocities, as VENUS, then the EARTH, and afterwards MARS, JUPITER, SATURN, and the GEORGIUM SIDUS.

Proceeding with attention in thus exploring and examining the heavens, he will perceive that the earth is always accompanied by a ſmall ſtar, Jupiter by four, Saturn by five,* and the Georgium Sidus by two: theſe ſometimes precede, at others follow; now paſs before, and then behind the planets they reſpectively attend. Theſe ſmall bodies he will call SECONDARY PLANETS, SATELLITES, or MOONS.

The obſerver, by remarking the exact time when each planet paſſes over ſome fixed ſtar, and the time they employ from their ſetting out, to their

* Dr. Herſchel has diſcovered two additional moons attendant on Saturn.

their return to the ſame ſtar again, will find the times elapſing between each ſucceſſive return of the ſame planet to the ſame ſtar, to be equal; and he would ſay, that the ſeveral planets deſcribe circles in different periods; but that each of them always completes it's own circle in the ſame ſpace of time.

He will further obſerve, that there are certain bodies, which at their firſt appearance are ſmall, obſcure, ill-defined, and that move very ſlow, but which afterwards increaſe in magnitude, light, and velocity, until they arrive at a certain ſize, when they loſe theſe properties, and diminiſh in the ſame manner as they before augmented, and at laſt diſappear. To theſe bodies, which he will find in all the regions of the heavens, moving in different directions, he will give the name of COMETS.

OF THE PATHS OF THE PLANETS.

Our obſerver will take notice, that the planets run ſucceſſively through thoſe conſtellations which he has denominated, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Piſces; and that they never move out of a certain ſpace, or zone, of the heavens, which he will call the ZODIAC.

He will find, by proceeding in his obſervation, that the orbits of the planets are not all in the ſame

plane, but that they croſs each other in different parts of the heavens; ſo that if he makes the orbit of any one planet a ſtandard, and conſiders it as having no obliquity, he would judge the paths of all the reſt to be inclined to it; each planet having one half of it's path on one ſide, and the other half on the oppoſite ſide of the ſtandard path, or orbit. Aſtronomers generally aſſume the earth's orbit, as the ſtandard from which to compute the inclination of the others, and call it the ECLIPTIC. The points where the orbits interſect each other, are called the NODES.

This inclination of the orbits to each other, may be rendered more familiar to the imagination,* by taking as many hoops as there are planets, with a wire thruſt through each, and thereby joined to that hoop which repreſents the ecliptic; the other hoops may be then ſet more or leſs obliquely to the repreſentative of the ecliptic.

The ſeveral orbits do not croſs or interſect the ecliptic in the ſame point, or at the ſame angles; but their nodes, or interſections, are at different parts of the ecliptic.

It ſhould, however, be obſerved here, that in ſpeaking of the orbits of the planets, nothing more is meant by this term, than the paths they paſs through in the open ſpace in which they move,

* Dr. Watts's Aſtronomy.

move, and in which they are retained by a celeſtial but continuous mechaniſm.

OF THE MOTION OF THE PLANETS ROUND THEIR AXIS.

By attentively conſidering, with a teleſcope, the ſurface of the primary planets, our ſolar obſerver will find, that ſome parts, or SPOTS, are more obſcure than others. By continued obſervation he will find, that theſe ſpots change their places, and move from one ſide of the planet to the other; then diſappear for a certain ſpace of time; after which, they again, for a while, become viſible on the ſide where they were firſt ſeen, always continuing the ſame motion nearly in an uniform manner. The diſtance between the ſpots grows wider as they advance from the edge towards the middle of the planet, and then grows narrow again as they paſs from the middle to the other edge. The time they are ſeen on the planet's diſk, is ſomewhat leſs than the time of their diſappearance.

From theſe circumſtances he will conclude, firſt, that theſe ſpots adhere to the body of the planet, and ſecondly, that each planet is a globe turning on it's axis, and has conſequently two motions, one whereby it is moved round it's axis in a ſhort time, the other by which it revolves round the ſun. Theſe motions may be eaſily conceived, by only imagining a ſmall ball to roll

round a large ſphere. The firſt of theſe motions, or that of a planet round it's axis, is called the DIURNAL MOTION; and the ſecond, or it's revolution round the ſun, is called the ANNUAL MOTION.

The tutor may in ſome meaſure realize to his pupil the foregoing heliocentric phænomena, by plate I. fig. 1, of the ſolar ſyſtem; or ſtill much better, by means of a planetarium: for by ſuppoſing himſelf on the braſs ball which repreſents the ſun, he will ſee that all the planets move round him in beautiful and harmonious order: If on account of their diſtance he refers their motions to the fixed ſtars; he will ſee how readily the periods of their revolutions may be obtained, by obſerving the time that elapſes between their ſetting out from any fixed point, or ſtar, and their returning to the ſame again. He will alſo ſee, that if the paths of the planets were in one plane, as in the inſtrument, they would all be transferred to one circle in the heavens.

When he underſtands theſe particulars, the tutor may proceed to ſhew him that theſe motions, which are ſo regular when viewed from the ſun, become intricate and perplexed when viewed from the earth; and infer from thence, that whenever "we examine the works of the Deity at a proper point of diſtance, ſo as to take in the whole of his deſign, we ſee nothing but uniformity, beauty, and preciſion." Thus the heavens

vens prefent us with a plan, which, though inexpreffibly magnificent, is yet regular beyond the power of invention; and the volume of the univerfe will be found to be as perfect as it's author, containing mines of truth for ever opening, fountains of good for ever flowing, an endlefs fucceffion of bright, and ftill brighter exhibitions of the glorious godhead, anfwering to the nature and idea of infinite fulnefs and perfection.

ESSAY I.

PART II.

OF THE PHÆNOMENA OF THE HEAVENS, AS SEEN FROM THE EARTH.

THE various appearances of the celeſtial bodies, as ſeen from the earth, are the facts which lay the foundation of all aſtronomical knowledge. To account for, and explain them, is it's principal buſineſs: a true idea of theſe phænomena is therefore a neceſſary ſtep to a knowledge of aſtronomy.

OF THE APPARENT MOTION OF THE SUN.

The firſt and moſt obvious phænomenon is the daily riſing of the ſun in the eaſt, and his ſetting in the weſt; after which the moon and ſtars appear, ſtill keeping the ſame weſterly courſe, till we loſe ſight of them altogether.

This cannot be long obſerved, before we muſt alſo perceive, that neither the ſun nor moon always riſe exactly at the ſame point of the heavens,

heavens. If we commence our obſervations of the ſun, for inſtance, in the beginning of March, we ſhall find him appear to riſe more to the northward every day, to continue longer above the horizon, to be more vertical, or higher, at mid-day; this continues till towards the end of June, when he moves backward in the ſame manner, and continues this retrograde motion till near the end of December, when it begins to move forwards, and ſo on.

It is this change in the ſun's place, that occaſions him to riſe and ſet in different parts of the horizon, at different times of the year. It is from hence that his height is ſo much greater in ſummer, than in winter. In a word, the change of the ſun's place in the heavens is the cauſe of the different length in the days and nights, and the viciſſitudes of the ſeaſons.

As the knowledge of the ſun's apparent motion is of great importance, and a proper conception of it abſolutely neceſſary, in order to form a true idea of the phænomena of the heavens, the reader will excuſe my dwelling ſomething longer upon it. If on an evening we take notice of ſome fixed ſtar near the place where the ſun ſets, and obſerve it for ſeveral ſucceſſive evenings, we ſhall find that it approaches the ſun from day to day, till at laſt it will diſappear, being effaced by his light, though but a few days before it was at a ſufficient diſtance from him. That it is the

ſun which approaches the ſtars, and not the ſtars the ſun, is plain, for this reaſon; the ſtars always riſe and ſet every day at the ſame points of the horizon, oppoſite to the ſame terreſtrial objects, and are always at the ſame diſtance from each other; whereas the ſun is continually changing both the place of it's riſing and ſetting, and it's diſtance from the ſtars.

The ſun advances nearly one degree every day, moving from weſt to eaſt; ſo that in 365 days we ſee the ſame ſtar near the ſetting ſun, as was obſerved to be near him on the ſame day in the preceding year. In other words, the ſun has returned to the place from whence he ſet out, or made what we call his annual revolution.

We cannot indeed obſerve the ſun's motion among the fixed ſtars, becauſe he darkens the heavens by his ſplendor, and effaces the feeble light of thoſe ſtars that are in his neighbourhood; but we can obſerve the inſtant of his coming to the meridian, and his meridional altitude; we can alſo compute what point of the ſtarry heaven comes to the ſame meridian, at the ſame time, and with the ſame altitude. The ſun muſt be at that point of the ſtarry heavens thus diſcovered. Or we can obſerve that point in the heavens, which comes to the meridian at midnight, with a declination as far from the equator on one ſide, as the ſun's is on the other ſide; and it is evident, the ſun muſt be in that part of the

the heavens, which is diametrically oppofite to this point. By either of thefe methods we can afcertain a feries of points in the heavens, through which the fun paffes, forming a circle called the ECLIPTIC.*

OF THE APPARENT PHÆNOMENA OF THE MOON.

The motion of the moon through the heavens, and her appearance therein, are ftill more remarkable than thofe of the fun, and engage the attention "by the nightly changes in her circling orb." At the new moon, or when fhe firft becomes vifible, fhe is feen in the weftern part of the heavens, at no great diftance from the fun. She increafes every night in fize, and removes to a greater diftance from the fun, till at laft fhe appears in the eaftern part of the horizon, when the fun is difappearing in the weftern. After this, fhe gradually removes further and further eaftward, till at laft fhe feems to approach the fun as nearly in the eaft as fhe did before in the weft, and rifes a little before him in the morning; whereas in the firft part of her courfe fhe fet in the weft, long after him. All thefe different appearances happen in the fpace of a month; after which they re-commence in the fame manner. "Sometimes half-reftoring day with her waxing brightnefs; fometimes waning

* The conformity of this definition of the ecliptic, with that given in page 18, will be feen hereafter.

waning into dimneſs, and ſcarcely ſcattering the nocturnal gloom."

There is ſometimes an irregularity in theſe appearances, particularly in harveſt-time, when the moon appears for ſeveral days to be ſtationary in the heavens, and to preſerve nearly the ſame diſtance from the ſun; in conſequence of which, ſhe riſes at that ſeaſon of the year nearly at the ſame hour for ſeveral nights.

Of the apparent Motion of the Stars.

In contemplating the ſtars, it is obſerved that ſome among them have the ſingular property of neither riſing in the eaſt, nor ſetting in the weſt; but ſeem to turn round one immoveable point, near which is placed a ſingle ſtar, called the POLE, or POLE STAR.

This point is more or leſs elevated, according to the part of the earth from which it is viewed. Thus to the inhabitants of Lapland it is much more vertical, or elevated above the horizon, than with us: we ſee it more elevated than the inhabitants of Spain: and theſe again ſee it more elevated than thoſe of Barbary. By continually travelling ſouthward, we ſhould at laſt ſee the pole ſtar depreſſed to the horizon, and the other pole would appear in the ſouth part of the horizon, round which the ſtars in that part would revolve. There is, however, no ſtar in the ſouthern hemiſphere ſo near the pole, as that

that in the northern hemiſphere. Suppoſing us ſtill to travel ſouthward, the north pole would entirely diſappear, and the whole hemiſphere would ſeem to turn round a ſingle point in the ſouth, as the northern hemiſphere appears to turn round the pole ſtar.

The general appearance, therefore, of the ſtarry heavens, is that of a vaſt concave ſphere turning round two fixed points (diametrically oppoſite to each other, the one in the north, the other in the ſouth) once in twenty four hours.

Hence it is that the ſtars, though they keep the ſame relative places with reſpect to each other, yet change their ſituation very ſenſibly with reſpect to the horizon; ſome riſing above, others deſcending below it; ſome that were inviſible, now becoming viſible; while, on the other hand, many are diſappearing. Some never deſcend below the horizon; although as they turn round, they are ſometimes nearer to, at others further from it, deſcribing whole circles about a point above it. If the obſerver turns himſelf round, he will find ſome ſtars riſe only as it were to ſet again; many deſcribing ſmall arcs, and others larger ones.

The Appearances of the Planets.

Beſides the fixed ſtars, there are other bodies in the heavens, which are continually changing their places, both with reſpect to the ſtars, and

one

one another; theſe are called PLANETS. They move among the ſigns of the zodiac, never departing far from the ecliptic. Their apparent motion is very irregular, confuſed, and perplexed; ſometimes they appear as going forwards, ſometimes backwards, and at others are ſtationary.

MERCURY emits a bright white light, but keeps ſo near the ſun, that he is very ſeldom viſible; and when he does make his appearance, his motion towards the ſun is ſo ſwift, that he can only be diſcerned for a ſhort time. He appears a little after ſun-ſet, and again a little before ſun-riſe.

VENUS is the moſt beautiful ſtar in the heavens, known by the names of the morning and evening ſtar. She alſo, like Mercury, keeps near the ſun, though ſhe recedes from him much further, and like him, is never ſeen in the eaſtern quarter of the heavens when the ſun is in the weſtern; but always either attends him in the evening, or gives notice of his approach in the morning.

MARS is of a red fiery colour, giving a much duller light than VENUS, though he ſometimes appears almoſt equal to her in ſize. He is not ſubject to the ſame limitations in his motions as Venus and Mercury, but appears ſometimes very near the ſun, at others at a greater diſtance from him, riſing when the ſun ſets, or ſetting when he riſes.

JUPITER

JUPITER and SATURN likewiſe often appear at great diſtances from the ſun. The former ſhines with a bright light, the latter with a pale faint one. The motion of Saturn among the fixed ſtars is ſo ſlow, that unleſs carefully obſerved, and that for ſome time, he will not be thought to move at all.

The GEORGIUM SIDUS is the planet diſcovered by Dr. Herſchel. It is reckoned to be twice the diſtance of Saturn from the ſun, but cannot be readily perceived without the aſſiſtance of a teleſcope.

From the preceding obſervations, any perſon may eaſily learn to diſtinguiſh all the planets. For if after ſun-ſet he ſees a planet nearer the eaſt than the weſt, he may conclude that it is neither Mercury nor Venus; and may determine whether it be Saturn, Jupiter, or Mars, by the colour and light; by which, alſo, he may diſtinguiſh between Venus and Mercury.

That the light of each planet has it's peculiar tinge; and that there are certain fixed ſtars that have the ſame tints, was known to the Chaldæans. It is an obſervation beſt verified in thoſe countries, where the air is cleareſt.

Beſides the motions which we obſerve in all the planets, their apparent magnitudes are very different, at different times. Every one muſt have obſerved, that Venus, though ſhe conſtantly appears with great ſplendor, is not always

ways of the ſame ſize: but this difference of magnitude is moſt conſpicuous in Mars, it is remarkable in Jupiter, but leſs ſo in Saturn and Mercury.

The only phænomena viſible to the unaſſiſted ſight, beſides thoſe already deſcribed, are thoſe unexpected obſcurations of the ſun and moon, called ECLIPSES, of which we ſhall hereafter ſpeak more particularly.

We have now deſcribed thoſe appearances, which are the moſt ſtriking to every perſon who has paid the leaſt attention to what is paſſing over his head. The tutor would do well in this place, firſt, to bring his pupil acquainted with the appearances themſelves, and then explain them to him by the globe, or ſome other inſtrument. It would not be amiſs, if he were now to inſtruct him by practical obſervations, and ſhew him, by a ſmall quadrant, how to meaſure the elevation of the ſtars, &c. always remembering that young minds are ever active in ſearch of impreſſions from external objects; and that theſe are more permanent than thoſe made by words: in the former the mind energizes, and is brought into action; in the latter, it is in a great degree paſſive.

ESSAY I.

PART III.

Of the Copernican, or Solar System.

AFTER having ftated what would be the appearances of the heavenly bodies, if we were placed at the center of the fyftem, and then given a general view of their phænomena, as feen from the earth; it will now be proper to fhew how the irregularities that are difcovered in one fituation, are to be reconciled with the harmony and order that would be vifible if they were to be feen from the other; or in other words, to fhew why the motions of the planets appear to us fo different from what they really are.

One of the ends for which man was formed, is to correct appearances and errors, by the inveftigation of truth: whoever confiders him attentively, from infancy to manhood, and from manhood

manhood to old age, will find him ever bufy in endeavouring to find fome reality, to fupply the place of the falfe appearances, by which he has hitherto been deceived.

It is the bufinefs of the prefent part of this effay, to correct the errors arifing from appearances, and to point out truth by a brief detail of the principal parts of the Copernican fyftem, which is now univerfally received, becaufe it rationally accounts for, and accords with the phænomena of the heavens.

" At the appointed time, when it pleafed the fupreme difpenfer of every good gift to reftore light to a bewildered world, and more particularly to manifeft his wifdom in the fimplicity, as well as in the grandeur of his works, he opened the glorious fcene with a revival of found aftronomy;"* and raifed up Copernicus to difpel the darknefs in which it was then involved.

The Copernican fyftem confifts of the fun, feven primary, twelve fecondary planets, and the comets.

The feven planets, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Georgium Sidus, move round the fun,† in orbits included one within the other, and in the order here ufed in

* Pringle's Six Difcourfes to the Royal Society.

† The fun is not abfolutely at reft, being fubject to a fmall degree of motion, which is confidered in larger works on aftronomy,

in mentioning their names, Mercury being that which is neareſt the ſun.

Theſe ſeven, which revolve round the ſun as their center, are called PRIMARY PLANETS.

The fourteen ſmall planets revolve round the primary ones as a center, and are at the ſame time carried round the ſun with them; they are therefore called SECONDARY PLANETS, MOONS, OF SATELLITES.

The Georgium Sidus is attended by two moons, Saturn by ſeven, Jupiter by four, and the Earth by one; all of theſe, excepting the laſt, are inviſible to us, on account of the ſmallneſs of their ſize, and the greatneſs of their diſtance from us.

Mercury and Venus being within the Earth's orbit, are called INFERIOR PLANETS; but Mars, Jupiter, Saturn, and the Georgium Sidus, being without it, are called SUPERIOR PLANETS.

The orbits of all the planets are elliptical; but as the principal phænomena of the Copernican ſyſtem may be ſatisfactorily illuſtrated, by conſidering them as circular, the latter ſuppoſition is uſually adopted in giving a general idea of the diſpoſition and motion of the heavenly bodies.

It is clear, from a great variety of proofs, that the aſtronomers of antiquity were acquainted with the true ſolar ſyſtem, as revived by Copernicus. It was the univerſal doctrine of the Pythagorean ſchool, and is clearly marked out

as ſuch by Ariſtotle: for theſe, ſays he, aſſert that fire is in the midſt of the world, and that the earth is one of the heavenly bodies. He afterwards ſpeaks of a ſet of men, who held a ſyſtem eſſentially ſimilar to that of the modern Semitychonic. Eudemus, in his hiſtory of aſtronomy, as cited by Anatolius, ſays, that Anaximander was the firſt who diſcovered the earth to be one of the heavenly bodies, and to move round the center of the world. Ariſtarchus held that the earth is carried round the ſun, in the circumference of a circle, of which the ſun itſelf is the center; and that the ſphere of the fixed ſtars is ſo immenſe, that the circle of the earth's annual orbit bears no greater proportion to it, than the center of any ſphere bears to it's whole ſurface. Philolaus, and others, declared the motion of the ſun, round about the earth, to be only apparent. They ſaw and felt the importance of his globe over our's, and ſuppoſing it's influence to extend to much larger bounds than that of the earth, they placed it in the center of the univerſe. Among the Romans, we find that Numa built a temple to repreſent, as Plutarch interprets it,* the ſyſtem of the heavens, with a ſacred fire in the center of it.†

Thus

* Plutarch in Vita Numæ.

† Focum Veſtæ virginibus colendum dedit, UT AD SIMILITUDINEM CŒLESTIUM SIDERUM cuſtos imperii flamma vigilaret. Flor. Hiſt.

Thus alſo in the Jewiſh tabernacle, the ſeven lights had a reference to the ſeven chief lights of the heavens. Hence alſo the heavens are called in ſacred writ the tabernacle of the ſun; the whole of our ſyſtem dwelling within his influence. The foregoing citations are, we preſume, ſufficient to ſhew that the ancients were not ignorant of the true ſolar ſyſtem. Thoſe that want further information on this head, may conſult the notes to Sydenham's tranſlation of the Rivals of Plato, Duten's inquiries into the origin of the diſcoveries attributed to the moderns; Jones's eſſay on the firſt principles of natural philoſophy; Baillie hiſtoire de l'aſtronomie ancienne. But laying theſe authorities aſide, there are direct proofs to ſhew, that the moſt ancient ſages could not be ignorant of the true ſyſtem; theſe, however, muſt be left to ſome other occaſion.

We are greatly indebted to Copernicus for the revival of this ſyſtem, and being bold enough to avow it, though it was entirely oppoſed to the prejudices of the age he lived in. In praiſing of Copernicus, let us not, however, endeavour to do away the well-earned fame of Ptolemy; his ſyſtem, though erroneous, was ingenious; with it the world was content for many ages. It was then conſidered as founded upon invincible demonſtration, as a ſacred truth, that could not be weakened by the powers of controverſy, or ſhaken by the fluctuations of opinion.

Being in poſſeſſion of higher truth, we ſhould not ſpeak degradingly of thoſe who preceded us. If the ground we ſtand on be firm, it will not need ſupport from the empty boaſtings of declamation, the authority of names, or the contemptuous ſneers of an affected diſdain: and it is much to be regretted, that the writings of modern philoſophers furniſh us with many inſtances of the high opinion they entertain of their own knowledge, and their contempt of thoſe who differ from them. Let the young pupil therefore be cautioned not to confine the idea of bigotry to the ſuperſtitious zealots of religion; for he will find as much attachment to trifles, as much blind prejudice, and as little love to truth FOR TRUTH'S SAKE, among thoſe who are called philoſophers, as among the moſt inveterate ſectarians, or the wildeſt fanatics.

Let him early learn to diſtinguiſh the different degrees of evidence, of which each ſubject is capable; but above all, let him ſtudiouſly avoid the improper conjunction of the demonſtrative evidence of one ſcience, with the bare probability, or unfounded aſſertions in another; leſt, like thoſe who have gone before him, he ſhould call that demonſtrated, which is often not even probable.

Definitions.

Before we enter into a defcription of the folar fyftem, it may be neceffary to define what is meant by the axis of a planet; left the pupil fhould conceive them to turn on fuch material axes, as are ufed in the machines which are contrived to reprefent the planetary fyftem.

The AXIS OF A PLANET is a line conceived to be drawn through it's center, and about which it is conceived to turn, in the courfe of it's revolution round the fun: the extremities of this line terminate in oppofite points of the furface of the planet, and are called it's POLES; that which points towards the northern part of the heaven, is called the NORTH POLE; that which points towards the fouthern, the SOUTH POLE. A ball whirled from the hand into the open air, turns round upon a line within itfelf, while it is moving forward; fuch a line as this is meant, when we fpeak of the axis of a planet.

Fig. 1, plate I. reprefents the folar fyftem, wherein ☉ denotes the fun; A B the circle which the neareft planet, Mercury, defcribes in moving round it; C D that in which Venus moves; F G the orbit of the earth; H K that of Mars; I N that of Jupiter; O P that of Saturn; and Q R that of the Georgium Sidus; beyond this are the ftarry heavens.

The ſun and the planets are ſometimes expreſſed by marks or characters, inſtead of writing their names at length. The characters are as follow: ☉ the ſun, ☿ Mercury, ♀ Venus, ⊕ the Earth, ♂ Mars, ♃ Jupiter, ♄ Saturn.

Of the Sun.

The ſun is the center of the ſyſtem, round which the reſt of the planets revolve. It is the firſt and greateſt object of aſtronomical knowledge, and is alone enough to ſtamp a value on the ſcience, to which the ſtudy of it belongs. The ſun is the parent of the ſeaſons; day and night, ſummer and winter, are among it's ſurprizing effects. All the vegetable creation are the offspring of it's beams; our own lives are ſupported by it's influence. Nature revives, and puts on a new face, when it approaches nearer to us in ſpring; and ſinks into a temporary death at his departure from us in the winter.

Hence it was, with propriety, called by the ancients COR CŒLI, the heart of heaven; for as the heart is the center of the animal ſyſtem, ſo is the ſun the center of our univerſe. As the heart is the fountain of the blood, and the center of heat and motion; ſo is the ſun the life and heat of the world, and the firſt mover of the mundane ſyſtem. When the heart ceaſes to beat, the circuit of life is at an end; and if the ſun ſhould ceaſe to act, a total ſtagnation would

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take place throughout the whole frame of nature.

"By his magnetic beam he gently warms
The univerfe, and to each inward part,
With gentle penetration, though unfeen,
Shoots invifible virtue."

The fun is placed near the center of the orbits of all the planets, and turns round his axis in twenty-five $\frac{1}{4}$ days. It is inclined to the ecliptic in an angle of eight degrees. His apparent diameter, at a mean diftance from the earth, is about thirty-two minutes, twelve feconds.

Thofe who are not accuftomed to aftronomical calculation, will be furprized at the real magnitude of this luminary; which, on account of it's diftance from us, appears to the eye not much larger than the moon, which is only an attendant on our earth. When looking at the fun, they are viewing a globe, whofe diameter is 890,000 Englifh miles, whofe furface contains 2,488,461,360,000 fquare miles; whereas the earth is not more in diameter than 7970 miles: fo that the fun is about 1,392,500 times bigger than the earth. It is reckoned to be 539 $\frac{1}{2}$ times bigger than all the planets put together. Thus as it is the fountain of light and heat to all the planets, fo it alfo far furpaffes them in it's bulk. In proportion as fcience has advanced, and more accurate inftruments have been made, the magnitude of this luminary has been found

to exceed confiderably the limits of former calculations.

If the fun were every where equally bright, his rotation on his axis would not be perceptible; but by means of the fpots, which are vifible on his pure and lucid furface, we are enabled to difcover this motion.

When a fpherical body is near enough to appear of it's true figure, this appearance is owing to the fhading upon the different parts of it's furface: for as a flat circular piece of board, when it is properly fhaded by painting, will look like a fpherical body; fo a fpherical body appears of it's true fhape, for the fame reafon that the plane board, in the prefent inftance, appears fpherical. But if the fphere be at a great diftance, this difference of fhading cannot be difcerned by the eye, and confequently the fphere will no longer appear of it's true fhape; the fhading is then loft, and it feems like a flat circle.

It is thus with the fun; it appears to us like a bright flat circle, which flat circle is termed the SUN'S DISK. By the affiftance of telefcopes, dark fpots have been obferved on this difk, and found to have a motion from eaft to weft; their velocity is greater when they are at the center, than when they are near the limb. They are feen firft on the eaftern extremity, by degrees they come forwards towards the middle, and fo pafs on,

on, till they reach the weſtern edge; they then diſappear; and after they have lain hid about the ſame time that they continued viſible, they will appear again as at firſt. By this motion we diſcover not only the time the ſun employs in turning round his axis, but alſo the inclination of it's axis to the plane of the ecliptic.*

The page of hiſtory informs us, that there have been periods, when the ſun has wanted of it's accuſtomed brightneſs, ſhone with a dim and obſcure light for the ſpace of a whole year. This obſcurity has been ſuppoſed to ariſe from his ſurface being at thoſe times covered with ſpots. Spots have been ſeen that were much larger than the earth.

The ſun is ſuppoſed to have an atmoſphere round it, which occaſions that appearance which is termed the ZODIACAL LIGHT. This light is ſeen at ſome ſeaſons of the year, either a little after ſun-ſet, or a little before ſun-riſe. It is faintly bright, and of a whitiſh colour, reſembling the milky way. In the morning it becomes brighter

* The young obſerver may view the ſpots of the ſun with a refracting teleſcope of two or three feet, or a reflecting one of 12 inches, 18 inches, or two feet, taking care to guard the eye with a dark glaſs, to take off the glaring light; or the image or picture of the ſun, with his ſpots, may be thrown into a dark room, through a teleſcope, and received upon a piece of paper placed nearer or further from the glaſs at pleaſure.

brighter and larger, as it riſes above the horizon, till the approach of day, which diminiſhes it's ſplendor, and renders it at laſt inviſible. It's figure is that of a flat or lenticular ſpheroid, ſeen in profile. The direction of it's longer axis coincides with the plane of the ſun's equator. But it's length is ſubject to great variation, ſo that the diſtance of it's ſummit from the ſun, varies from 45 to 120 degrees. It is ſeen to the beſt advantage about the ſolſtices. It was firſt deſcribed and named by Caſſini, in 1683; it was noticed by Mr. Childrey, about the year 1650.

Of the inferior Planets, Mercury and Venus.

Of Mercury. ☿

Of all the planets, Mercury is the leaſt; at the ſame time, it is that which is neareſt the ſun. It is from his proximity to this globe of light, that he is ſo ſeldom within the ſphere of our obſervation, being loſt in the ſplendor of the ſolar brightneſs, yet it emits a very bright white light. It is oftener ſeen in thoſe parts of the world, which are more ſouthward than that which we inhabit; and oftener to us than to thoſe who live nearer the north pole; for the more oblique the ſphere is, the leſs is the planet's elevation above the horizon.

Mercury

Mercury never removes but a few degrees from the ſun. The meaſure of a planet's ſeparation, or diſtance, from the ſun, is called it's ELONGATION. His greateſt elongation is little more than twenty-eight degrees, or about as far as the moon appears to be from the ſun, the ſecond day after new moon. In ſome of it's revolutions, the elongation is not more than eighteen degrees.

Mercury is computed to be at 36,841,468 miles from the ſun, and to revolve round him in 87 days, 23 hours, 16 minutes, which is the meaſure of it's year, about one-fourth of our's. As from the nearneſs of this planet to the ſun, we neither know the time it revolves round it's axis, nor the inclination of that axis to the plane of it's orbit, we are neceſſarily ignorant of the length of it's day and night, or the variety of ſeaſons it may be liable to. Mercury is 3000 miles in diameter, and therefore contains in ſurface 28,274,400 ſquare miles. Large as Mercury, when thus conſidered, appears to be, it is but an atom, when compared with Jupiter, whoſe diameter is 94000 miles. It's apparent diameter, at a mean diſtance from the earth, is 20 ſeconds.

Mercury is ſuppoſed to move at the rate of $109{,}699\frac{58}{100}$ miles per hour. The ſun is 26,109,963 times as big as Mercury; ſo that it would appear to the inhabitants of Mercury nearly three times larger than it does to us; and it's diſk, or face, about ſeven times the ſize we

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ſee it. As the other five planets are above Mercury, their phænomena will be nearly the ſame to it as to us. Venus and the earth, when in oppoſition to the ſun, will ſhine with full orbs, and afford a brilliant appearance to the Mercurian ſpectator.

Mercury, like the moon, changes it's phaſes, according to it's ſeveral poſitions, with reſpect to the ſun and earth. He never appears quite round or full to us, becauſe his enlightened ſide is never turned directly towards us, except when he is ſo near the ſun, as to become inviſible. The times for making the moſt favourable obſervations on this planet, are, when it paſſes before the ſun, and is ſeen traverſing his diſk, in the form of a black ſpot. This paſſage of a planet over the face of the ſun, is called a TRANSIT. It happens in it's lower conjunction, at a particular ſituation of the nodes; which leads us to mention their place in the ecliptic.

The angle formed by the inclination of the orbit of Mercury with the plane of the ecliptic, is 6° 59′; the node from which Mercury aſcends northward, above the plane of the ecliptic, is 16° 1′ 30″; in Taurus, the oppoſite one, 14° 1′ 24″; in Saggitarius, it's nodes move forward about 50″ per year.

If Mercury, at his inferior conjunction, comes to either of his nodes about theſe times, he will appear to TRANSIT over the diſk of the ſun.

But in all other parts of his orbit his conjunctions are inviſible, becauſe he either goes above or below the ſun.

Of Venus. ♀

Venus is the brighteſt and largeſt, to appearance, of all the planets, diſtinguiſhed from them all by a ſuperiority of luſtre; her light is of a white colour, and ſo conſiderable, that in a duſky place ſhe projects a ſenſible ſhade.

The diameter of Venus is 9330 miles; ſhe contains 270,299,808 ſquare miles; her diſtance from the ſun is 68,891,486 miles; ſhe goes round the ſun in 224 days, 6 hours, 41 minutes, moving at the rate of $80,295\frac{24}{100}$ miles per hour. It's axis is inclined to the plane of it's orbit, in an angle of 75 degrees. Her orbit makes an angle of 2° 23′ with the ecliptic; one node is at the 14° 43′ of Gemini, the other about 7° 55′ in Aquarius. The nodes move forward 31″ per year; her apparent diameter at a mean diſtance from the earth, is 1′ 20″. Her motion round her axis has been fixed by ſome at 23 hours; by others at above 24 days. She, like Mercury, conſtantly attends the ſun, never departing from him above 47 or 48 degrees. Like Mercury, ſhe is never ſeen AT MIDNIGHT, OR IN OPPOSITION TO THE SUN, being viſible only for three or four hours in the morning, or evening, according as ſhe is before or after the ſun.

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One would not imagine that this planet, which appears so much superior to Saturn in the heavens, is so inconsiderable when compared to it; for the diameter of Saturn is 78,000 miles; while, on the other hand, one would scarce imagine that Venus, which appears but as a lucid spangle in the heavens, was so large a globe as she truly is, her diameter being 9330 miles. It is the distance which produces these effects; which gives and takes away the magnitude of things. Her apparent size varies with her distance; at some seasons she appears nearly 32 times larger than at others.

When this planet is in that part of it's orbit which is west of the sun, that is, from her inferior to her superior conjunction, she rises before him in the morning, and is called PHOSPHORUS, or LUCIFER, or the MORNING STAR. When she appears east of the sun, that is, from her superior to her inferior conjunction, she sets in the evening after him; or in other words, shines in the evening after he sets, and is called HESPERUS, or VESPER, or the EVENING STAR.

The inhabitants of Venus will see the planet Mercury always accompanying the sun; and he will be to them, by turns, an evening or a morning star, as Venus is to us. To the same inhabitants, the sun will appear almost twice as large as he does to us.

Venus,

Venus, when viewed through a telefcope, is feldom feen to fhine with a full face; but has phafes, juft like the moon, from the fine thin crefcent to the enlightened hemifphere. Her illuminated part is conftantly turned towards the fun; hence it's horns are turned towards the eaft when it is a morning ftar, and towards the weft when it is an evening ftar. Some aftronomers have thought they perceived a fatellite moving round Venus, but as fucceeding obfervers have not been able to verify their obfervations, they are fuppofed to have originated in error. In obferving the tranfit of Venus, Mr. Dunn, and other gentlemen, faw a penumbra which took place about five feconds before the contact, preceding the egrefs of the planet; and from thence they concluded, that it had an atmofphere of about 50 geographical miles in height.

We are told, that, when Copernicus firft publifhed his account of the folar fyftem, it was objected to him that it could not be true, becaufe if it was, the inferior planets muft have different phafes, according to their different fituation with refpect to the fun and earth; whereas they always appear round to us. The anfwer faid to be made by him, is, that they appear round to the eye by reafon of their diftance; but if we could have a nearer, or more diftinct view of them, we fhould fee in them the fame phafes we do in the moon. The invention of telefcopes

is ſaid to have verified this prediction of Copernicus. But it is neither probable, that a defender of the Ptolemaic ſyſtem ſhould make ſuch an objection, or Copernicus ſuch an anſwer; ſince in the Ptolemaic, as well as in the Copernican ſyſtem, the ſhape of theſe planets ought to change, juſt as the moon does; conſequently, the mere change of ſhape in the inferior planets is an argument, which, in the common way of urging it, proves nothing at all as to the truth or falſhood of the Copernican ſyſtem. If, beſides the changes of ſhape made in the inferior planets, we conſider the ſituation of the planets with reſpect to the ſun, when theſe changes happen; this, indeed, will ſhew us, that the Ptolemaic ſyſtem is falſe,* as will be ſeen in a ſubſequent part of theſe eſſays.

Taking the times in which the planets move round the ſun, for the length of their year; and the times of their turning round their axes, for the length of their days and nights together; and aſſuming, as true, the obſervations of Bianchini, relative to the rotation of Venus round her axis; we may ſay, that a day and a night in Venus is as long as 23 ½ days and nights with us; her axis inclines 75 degrees from the axis of her orbit, on which account the length of her days and nights differ

* Rutherford's Syſtem of Natural Philoſophy, vol. 2, p. 781.

differ much more in proportion, and the variation of her ſeaſons is greater than thoſe of our earth. She very ſeldom has the forenoon and afternoon of the ſame day of an equal length. At her equator ſhe has the four ſeaſons twice every year, with other peculiarities, which are enumerated in larger treatiſes on this ſubject.

Venus is ſometimes ſeen paſſing over the diſk of the ſun, as a round dark ſpot. Theſe appearances, which are called tranſits, happen very ſeldom; though there have been two within theſe few years, the one in June, 1761, the other in June, 1769; the next will be in the year 1874.

Of the Earth. ⊕

The next planet that comes before us is the earth that we inhabit; ſmall as it really is when compared to ſome of the other planets, it is to us of the higheſt importance: we wiſh only to attain knowledge of others, that we may find out their relation to this, and from thence learn our connection with the univerſe at large. But when viewed with an eye to eternity, it's value to us is heightened in a manner that exceeds expreſſion, and ſurpaſſes all the powers of the human mind. He alone can form ſome idea of it, who in the regions of celeſtial bliſs is become a partaker of the length and breadth, the depth and height, of divine love.

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The orbit of the earth is placed between thoſe of Venus and Mars. The diameter of the earth is 7970 miles; it's ſurface contains 199,557,259 ſquare miles; it's diſtance from the ſun is 95,173,000 miles, and goes round him in a year, moving at the rate of 68,243$\frac{24}{100}$ miles per hour. It's apparent diameter, as ſeen from the ſun, is about 21 ſeconds.

It turns round it's axis, from WEST TO EAST, in twenty-four hours, which occaſions the apparent diurnal motion of the ſun, and all the heavenly bodies round it, from EAST TO WEST, in the ſame time; it is, of courſe, the cauſe of their riſing and ſetting, of day and night.

The axis of the earth is inclined 23$\frac{1}{2}$ degrees to the plane of it's orbit, and keeps in a direction parallel to itſelf, throughout it's annual courſe, which cauſes the returns of ſpring and ſummer, autumn and winter. Thus his diurnal motion gives us the grateful viciſſitude of night and day, and his annual motion the regular ſucceſſion of ſeaſons.

OF THE MOON. ☾

Next to the ſun, the moon is the moſt ſplendid and ſhining globe in the heavens, the ſatellite, or inſeparable companion of the earth. By diſſipating, in ſome meaſure, the darkneſs and horrors of the night; ſubdividing the year into months;

months; and regulating the flux and reflux of the ſea; ſhe not only becomes a pleaſing, but a welcome object; an object affording much for ſpeculation to the contemplative mind, of real uſe to the navigator, the traveller, and the huſbandman. The Hebrews, the Greeks, the Romans, and, in general, all the ancients uſed to aſſemble at the time of new moon, to diſcharge the duties of piety and gratitude for it's manifold uſes.

That the moon appears ſo much larger than the other planets, is owing to her vicinity to us; for to a ſpectator in the ſun ſhe would be ſcarcely viſible, without the aſſiſtance of a teleſcope. Her diſtance is but ſmall from us, when compared with that of the other heavenly bodies; for among theſe, the leaſt abſolute diſtance, when put down in numbers, will appear great, and the ſmalleſt magnitude immenſe.

The moon is 2180 miles in diameter; her bulk is in proportion to the earth as 1 to $48\frac{6}{10}$; her diſtance from the center of the earth 240,000 miles; ſhe goes round her orbit in 27 days, 7 hours, 43 minutes, moving at the rate of $2299\frac{65}{100}$ miles per hour. The time in going round the earth, reckoning from change to change, is 29 days, 12 hours, 44 minutes. Her apparent diameter at a mean diſtance from the earth is $31'\ 16\frac{1}{2}''$; but as viewed from the ſun, at a mean diſtance about $6''$.

Her orbit is inclined to the ecliptic, in an angle of 5 degrees, 18 minutes, cutting it in two points, which are diametrically oppoſite to each other; theſe points are called her nodes. The nodes have a motion weſtward, or contrary to the order of the ſigns, making a complete revolution in about nineteen years; in which time, each node returns to that point of the ecliptic whence it before receded.

If the moon were a body poſſeſſing native light, we ſhould not perceive any diverſity of appearance; but as ſhe ſhines entirely by light received from the ſun, and reflected by her ſurface, it follows, that according to the ſituation of the beholder with reſpect to the illuminated part, that he will ſee more or leſs of her reflected beams: for only one half of a globe can be enlightened at once.

Hence, while ſhe is making her revolution round the heavens, ſhe undergoes great changes in her appearance. She is ſometimes on our meridian at midnight, and therefore in that part of the heavens which is oppoſite to the ſun; in this ſituation ſhe appears as a complete circle, and it is ſaid to be FULL MOON. As ſhe moves eaſtward, ſhe becomes deficient on the weſt ſide, and in about $7\frac{1}{3}$ days comes to the meridian, at about ſix in the morning, having the appearance of a ſemicircle, with the convex ſide turned towards the ſun; in this ſtate, her appearance is called

called the HALF MOON. Moving on ftill eaftward, fhe becomes more deficient on the weft, and has the form of a crefcent, with the convex fide turned towards the fun; this crefcent becomes continually more flender, till about fourteen days after the full moon fhe is fo near the fun, that fhe cannot be feen, on account of his great fplendor. About four days after this difappearance, fhe is feen in the evening, a little to the eaftward of the fun, in the form of a fine crefcent, with the convex fide turned from the fun; moving ftill to the eaftward, the crefcent becomes more full; and when the moon comes to the meridian, about fix in the evening, fhe has again the appearance of a bright femicircle; advancing ftill to the eaftward fhe becomes fuller on the eaft fide; at laft, in about 29 ½ days, fhe is again oppofite to the fun, and again full.

It frequently happens, that the moon is eclipfed when at the full; and that the fun is eclipfed fometime between the difappearance of the moon in the morning on the weft fide of the fun, and her appearance in the evening on the eaft fide of the fun. The nature of thefe phænomena will be more fully confidered, when we come to treat particularly of eclipfes.

In every revolution of the moon about the earth, fhe turns once round upon her axis, and therefore always prefents the fame face to our view; and as, during her courfe round the earth,

the ſun enlightens ſucceſſively every part of her globe only once, conſequently ſhe has but one day in all that time, and her day and night together are as long as our lunar month. As we ſee only one ſide of the moon, we are therefore inviſible to the inhabitants on the oppoſite ſide, without they take a journey to that ſide which is next to us, for which purpoſe ſome of them muſt travel more than 1500 miles.

As the moon illuminates the earth by a light reflected from the ſun, ſhe is reciprocally enlightened, but in a much greater degree, by the earth; for the ſurface is above thirteen times greater than that of the moon; and therefore, ſuppoſing their power of reflecting light to be equal, the earth will reflect thirteen times more light on the moon than ſhe receives from it. When it is what we call new moon, we ſhall appear as a full moon to the Lunarians; as it increaſes in light to us, our's will decreaſe to them: in a word, our earth will exhibit to them the ſame phaſes as ſhe does to us.

We have already obſerved, that from one half of the moon the earth is never ſeen; from the middle of the other half, it is always ſeen over head, turning round almoſt thirty times as quick as the moon does. To her inhabitants, the earth ſeems to be the largeſt body in the univerſe, about thirteen times as large to them, as ſhe does to us. As the earth turns round it's axis, the

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ſeveral continents and iſlands appear to the Lunarians as ſo many ſpots, of different forms; by theſe ſpots, they may determine the time of the earth's diurnal motion; by theſe ſpots, they may, perhaps, meaſure their time,—they cannot have a better dial.

Of the superior Planets.

Mars, Jupiter, Saturn, and the Georgium Sidus, are called ſuperior planets, becauſe they are higher in the ſyſtem, or farther from the center of it, than the earth is.

They exhibit ſeveral phænomena, which are very different from thoſe of Mercury and Venus; among other things, they come to our meridian both at noon and midnight, and are never ſeen croſſing the ſun's diſk.

Of Mars. ♂

Mars is the leaſt bright and elegant of all the planets; it's orbit lies between that of the earth and Jupiter, but very diſtant from both. He appears of a duſky reddiſh hue; from the dullneſs of his appearance, many have conjectured that he is encompaſſed with a thick cloudy atmoſphere; his light is not near ſo bright as that of Venus, though he is ſometimes nearly equal to her in ſize.

Mars, which appears ſo inconſiderable in the heavens, is 5,400 miles in diameter, 91,608,956 ſquare miles in ſuperficial content. It's diſtance from the ſun is 145,014,148 miles. It goes round the ſun in 1 year, 321 days, 17 hours, moving at the rate of 55,287 miles per hour. It revolves round it's axis in 24 hours, 40 minutes; it's orbit is inclined to the ecliptic, at an angle of 1° 52′; it's aſcending node about 17°17′ in Taurus. To an inhabitant in Mars, the ſun would appear one-third leſs in diameter than it does to us. It's apparent diameter, as viewed at a mean diſtance from the earth, is 30 ſeconds.

Mars, when in oppoſition to the ſun, is five times nearer to us than when in conjunction. This has a very viſible effect on the appearance of the planet, cauſing him to appear much larger at ſome periods than at others.

The inclination of the axis to it's orbit is 61° 18′, and conſequently the obliquity of the ecliptic is 28°42′; the inclination of the orbit is 1°51′; the node Taurus 21° 4′.

The analogy between Mars and the earth is by far the greateſt in the whole ſolar ſyſtem; their diurnal motion is nearly the ſame; the obliquities of their reſpective ecliptics not very different. Of all the ſuperior planets, that of Mars is by far the neareſt like the earth: nor will the Martial year appear ſo diſſimilar to our's, when we compare it with the long duration of the years of Jupiter,

Jupiter, Saturn, and the Georgium Sidus. It probably has a confiderable atmofphere; for befides the permanent fpots on it's furface, Dr. Herfchel has often perceived occafional changes of partial bright belts, and alfo once a darkifh one in a pretty high latitude; alterations which we can attribute to no other caufe than the variable difpofition of clouds and vapours floating in the atmofphere of the planet.

A fpectator in Mars will rarely, if ever, fee Mercury, except when they fee it paffing over the fun's difk. Venus will appear to him at about the fame diftance from the fun, as Mercury appears to us. The earth will appear about the fize of Venus, and never above 48 degrees from the fun; and will be, by turns, a morning and evening ftar to the inhabitants of Mars. It appears, from the moft accurate obfervations, that Mars is a fpheroid, or flatted fphere, the equatorial diameter to the polar being in the proportion of about 131 to 127; and there is reafon to fuppofe, that all the planets are of this figure.

Of Jupiter. ♃

Jupiter is fituated ftill higher in the fyftem, revolving round the fun, between Mars and Saturn. It is the largeft of all the planets, and eafily diftinguifhed from them by his peculiar magnitude and light. To the naked eye it appears

pears almoſt as large as Venus, but not altogether ſo bright.

Jupiter revolves round it's axis in 9 hours, 56 minutes; it's revolution in it's orbit to the ſame point of the ecliptic is 11 years, 313 days, 8 hours. The diſproportion of Jupiter to the earth, in ſize, is very great; viewing him in the heavens, we conſider him as ſmall in magnitude; whereas he is in reality 94,000 miles in diameter, and 27,759,177,600 ſquare miles in ſuperficial content; his diſtance from the ſun is 494,990,976 miles; he moves at the rate of rather more than 29,083 miles per hour; his orbit is inclined to the ecliptic, at an angle of $2° 33\frac{1}{2}'$. It's apparent diameter, as ſeen at a mean diſtance from the earth, is $39''$.

To an eye placed in Jupiter, the ſun would not be a fifth part of the ſize he appears to us, and his diſk be 25 times leſs. Though Jupiter be the largeſt of all the planets, yet it's revolution round it's axis is the ſwifteſt. The polar axis is ſhorter than the equatorial one, and his axis perpendicular to the plane of his orbit.

Jupiter, when in oppoſition to the ſun, is much nearer the earth, than when he is in conjunction with him; at thoſe times he appears alſo larger, and more luminous than at other times.

In Jupiter, the days and nights are of an equal length, each being about five hours long. We have already obſerved, that the axis of his diurnal

rotation

rotation is nearly at right angles to the plane of his annual one, and confequently there can be fcarce any difference in feafons; and here, as far as we may reafon from analogy, we may difcover the footfteps of wifdom: for if the axis of this planet were inclined by any confiderable number of degrees, juft fo many degrees round each pole would, in their turn, be almoft fix years in darknefs; and as Jupiter is of fuch an amazing fize, in this cafe immenfe regions of land would be uninhabitable.

Jupiter is attended by four fatellites, or moons; thefe are invifible to the naked eye; but through a telefcope they make a beautiful appearance. As our moon turns round the earth, enlightening the nights, by reflecting the light fhe receives from the fun, fo thefe alfo enlighten the nights of Jupiter, and move round him in different periods of time, proportioned to their feveral diftances: and as the moon keeps company with the earth in it's annual revolution round the fun; fo thefe accompany Jupiter in it's courfe round that luminary.

In fpeaking of the fatellites, we diftinguifh them according to their places, into the firft, the fecond, and fo on; by the firft, we mean that which is neareft to the planet.

The outermoft of Jupiter's fatellites will appear almoft as big as the moon does to us; five times the diameter, and twenty-five times the

difk

diſk of the ſun. The four ſatellites muſt afford a pleaſing ſpectacle to the inhabitants of Jupiter; for ſometimes they will riſe all together, ſometimes be all together on the meridian, ranged one under another, beſides frequent eclipſes. Notwithſtanding the diſtance of Jupiter and his ſatellites from us, the eclipſes thereof are of conſiderable uſe, for aſcertaining with accuracy the longitude of places. From the four ſatellites the inhabitants of Jupiter will have four different kinds of months, and the number of them in their year not leſs than 4,500.

An aſtronomer in Jupiter will never ſee Mercury, Venus, the earth, or Mars: becauſe, from the immenſe diſtance at which he is placed, they muſt appear to accompany the ſun, and riſe and ſet with him; but then he will have for the objects of obſervation, his own four moons, Saturn, his ring and ſatellites, and probably the Georgium Sidus.

Of Saturn. ♄

Before the diſcovery of the Georgium Sidus, Saturn was reckoned the moſt remote planet in our ſyſtem; he ſhines but with a pale feeble light, leſs bright than Jupiter, though leſs ruddy than Mars. The uninformed eye imagines not, when it is directed to this little ſpeck of light, that it is viewing a large and glorious globe, one of the moſt ſtupendous of the planets, whoſe diameter

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is 78,000 miles, whofe furface contains 19,113,494,400 fquare miles. We need not, however, be furprized at the vaft bulk of Saturn, and it's difproportion to it's appearance in the heavens; for we are to confider, that all objects decreafe in their apparent magnitude, in proportion to their diftance; but the diftance of Saturn is immenfe; that of the earth from the fun is 95,173,000 miles; of Saturn, 907,956,130 miles!

The length of a planet's year, or the time of it's revolution round it's orbit, is proportioned to it's diftance from the fun. Saturn goes round the fun in 29 years, 167 days, 6 hours, moving at the rate of rather more than 22,101 miles per hour. His orbit is inclined to the ecliptic, in an angle of 2° 13′. His apparent diameter at a mean diftance from the earth is 16″.

It has not yet been afcertained by aftronomical obfervation, whether Saturn revolves or not upon his axis: we are therefore ignorant of the length of his day, and of his night. The fun's difk will appear ninety times lefs to an inhabitant of Saturn, than it does to us; but notwithftanding the fun appears fo fmall to the inhabitants of the regions of Jupiter and Saturn, the light that he will afford them is much more than would be at firft fuppofed; and calculations have been made, from which it is inferred, that the fun will afford 500 times as much light to Saturn, as

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the full moon to us; and 1600 times as much to Jupiter. To eyes like our's, unaſſiſted by inſtruments, Jupiter and the Georgium Sidus would be the only planets ſeen from Saturn, to whom Jupiter would ſometimes be a morning, ſometimes an evening ſtar.

One of the firſt diſcoveries of the teleſcope, when brought to a tolerable degree of perfection, was, that Saturn did not appear like other planets. Galileo, in 1610, ſuppoſed it compoſed of 3 ſtars, or globes, a larger in the middle, and a ſmaller on each ſide; and he continued his obſervations till the two leſſer ſtars diſappeared, and this planet looked like the others. Further obſervation ſhewed, that what Galileo took for two ſtars, were parts of a ring. This ſingular and curious appendage to the planet Saturn, is a thin, broad, opake ring, encompaſſing the body of the planet, without touching it, like the horizon of an artificial globe, appearing double when viewed through a good teleſcope. The ſpace between the ring and the globe of Saturn, is ſuppoſed to be rather more than the breadth of the ring, and the greateſt diameter of the ring to be in proportion to that of the globe, as 7 to 3; the plane of the ring is inclined to the plane of the ecliptic, in an angle of 30°, and is about 21,000 miles in breadth. It puts on different appearances to us, ſometimes being ſeen quite open, at others only as a line upon the equator. It is probable, that

that it will at times caſt a ſhadow over vaſt regions of Saturn's body. The ring of Saturn, conſidered as a broad flat ring of ſolid matter, ſuſpended round the body of the planet, and keeping it's place without any connection with the body, is quite different from all other planetary phænomena with which we are acquainted. Of the nature of this ring, various and uncertain were the conjectures of the firſt obſervers; though not more perplexed, than thoſe of the lateſt. Of it's uſe to the inhabitants of Saturn, we are as ignorant as of it's nature: though there are reaſons for ſuppoſing that it would appear to them as little more than a white or bright-coloured cloud. Some of the phænomena of Saturn's ring will be treated of more particularly in another part of this eſſay.

Saturn is not only furniſhed with this beautiful ring, but it has alſo ſeven attendant moons.

Of the Georgium Sidus.

From the time of Huygens and Caſſini, to the diſcovery of the Georgium Sidus by Dr. Herſchel, though the intervening ſpace was long, though the number of aſtronomers was increaſed, though aſſiduity in obſerving was aſſiſted by accuracy and perfection in the inſtruments of obſervation, yet no new diſcovery was made in

the heavens, the boundaries of our ſyſtem were not enlarged. The inquiſitive mind naturally inquires, why, when the number of thoſe that cultivated the ſcience was increaſed, when the ſcience itſelf was ſo much improved, in practical diſcoveries it was ſo deficient? A ſmall knowledge of the human mind will anſwer the queſtion, and obviate the difficulty. The mind of man has a natural propenſity to indolence; the ardour of it's purſuits, when they are unconnected with ſelfiſh views, are ſoon abated, ſmall difficulties diſcourage, little inconveniences fatigue it, and reaſon ſoon finds excuſes to juſtify, and even applaud this weakneſs. In the preſent inſtance, the unmanageable length of the teleſcopes that were in uſe, and the continual expoſure to the cold air of the night, were the difficulties the aſtronomer had to encounter with; and he ſoon perſuaded himſelf, that the ſame effects would be produced by ſhorter teleſcopes, with equal magnifying power; herein was his miſtake, and hence the reaſon why ſo few diſcoveries have been made ſince the time of Caſſini. A ſimilar inſtance of the retrogradation of ſcience, occurs in the hiſtory of the microſcope, as I have ſhewn in my eſſays on that inſtrument.

The Georgium Sidus was diſcovered by Dr. Herſchel, in the year 1781; for this diſcovery he obtained from the Royal Society the honorary recom-

pence of Sir Godfrey Copley's medal. He named the planet in honour of his Majesty King George III. the Patron of ſcience, who has taken Dr. Herſchel under his patronage, and granted him an annual ſalary. By this munificence he has given ſcope to a very uncommon genius, and enabled him to proſecute his favourite ſtudies with unremitted ardour.

In ſo recent a diſcovery of a planet ſo diſtant, many particulars cannot be expected. It's year is ſuppoſed to be more than 83 ſiderial years; it's diameter 34,217 miles; the inclination of it's orbit 43′ 35″; it's diameter, compared to that of the earth, as 431,769 to 1; in bulk it is 8,049,256 times as large as the earth. It's light is of a blueiſh white colour, and it's brilliancy between that of the moon and Venus.

Though the Georgium Sidus was not known as a planet till the time of Dr. Herſchel, yet there are many reaſons to ſuppoſe it had been ſeen before, but had then been conſidered as a fixed ſtar. Dr. Herſchel's attention was firſt engaged by the ſteadineſs of it's light; this induced him to apply higher magnifying powers to his teleſcope, which increaſed the diameter of it: in two days he obſerved that it's place was changed; he then concluded it was a comet; but in a little time he, with others, determined that it was a planet, from it's vicinity to the ecliptic, the direction of it's motion, being ſtationary in the time,

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and in ſuch circumſtances as correſpond with ſimilar appearances in other planets.

With a teleſcope, which magnifies about 300 times, it appears to have a very well-defined viſible diſk; but with inſtruments of a ſmaller power it can hardly be diſtinguiſhed from a fixed ſtar between the ſixth and ſeventh magnitude. When the moon is abſent, it may alſo be ſeen by the naked eye.

Dr. Herſchel has ſince diſcovered that it is attended by two ſatellites: a diſcovery which gave him conſiderable pleaſure, as the little ſecondary planets ſeemed to give a dignity to the primary one, and raiſe it into a more conſpicuous ſituation among the great bodies of our ſolar ſyſtem.

As the diſtances of the planets, when marked in miles, are a burden to the memory, aſtronomers often expreſs their mean diſtances in a ſhorter way, by ſuppoſing the diſtance of the earth from the ſun to be divided into ten parts. Mercury may then be eſtimated at four of ſuch parts from the ſun, Venus at ſeven, the earth at ten, Mars at fifteen, Jupiter at fifty-two ſuch parts, Saturn at ninety-five, and the Georgium Sidus 190 parts.

By comparing the periods of the planets, or the time they take to finiſh their revolutions, with their diſtance from the ſun, they are found to obſerve a wonderful harmony and proportion

to each other; for the nearer any planet is to the ſun, the ſooner does he finiſh his revolution. And in this there is a conſtant and immutable law, which all the bodies of the univerſe inviolably obſerve in their circulations; namely, THAT THE SQUARES OF THEIR PERIODICAL TIMES ARE AS THE CUBES OF THEIR DISTANCES FROM THE CENTER OF THEIR ORBITS ABOUT WHICH THEY REGULARLY PERFORM THEIR MOTIONS. We are indebted to the ſagacity of Kepler for the diſcovery of this law; he was indeed one of the firſt founders of modern aſtronomy.

We cannot conclude this general ſurvey of the ſolar ſyſtem better than in the words of that excellent mathematician, Mr. Maclaurin. The view of nature, which is the immediate object of ſenſe, is very imperfect, and of ſmall extent; but by the aſſiſtance of art, and the aid of reaſon, becomes enlarged, till it loſes itſelf in infinity. As magnitude of every ſort, abſtractedly conſidered, is capable of being increaſed to infinity, and is alſo diviſible without end; ſo we find, that in nature the limits of the greateſt and leaſt dimenſions of things are actually placed at an immenſe diſtance from each other.

" We can perceive no bounds of the vaſt expanſe, in which natural cauſes operate, and fix no limit, or termination, to the univerſe. The objects we commonly call great, vaniſh, when

we

we contemplate the vaſt body of the earth. The terraqueous globe itſelf is loſt in the ſolar ſyſtem; the ſun itſelf dwindles into a ſtar; Saturn's vaſt orbit, and all the orbits of the comets, crowd into a point, when viewed from numberleſs places between the earth and the neareſt fixed ſtars. Other ſuns kindle to illuminate other ſyſtems, where our ſun's rays are unperceived; but they alſo are ſwallowed up in the vaſt expanſe. When we have riſen ſo high, as to leave all definite meaſures far behind us, we find ourſelves no nearer to a term, or limit.

"Our views of nature, however imperfect, ſerve to repreſent to us, in a moſt ſenſible manner, that mighty power which prevails throughout, acting with a force and efficacy that ſuffers no diminution from the greateſt diſtances of ſpace or intervals of time; and to prove that all things are ordered by infinite wiſdom, and perfect goodneſs. Scenes which ſhould excite and animate us to correſpond with the general harmony of nature."*

Of the Shape or Figure of the Earth.

Having given a general idea of the Copernican ſyſtem, and the bodies of which it is compoſed, it will be neceſſary to enlarge theſe ideas by a more minute deſcription of the particular parts,

*Maclaurin.

parts, which form this great whole; and to ſtrengthen them by the force of that evidence, on which the ſyſtem is founded.

We have already obſerved, that the appearance of the heavenly bodies is not the ſame to the inhabitants of various parts of the earth; that the ſun, the moon, and the ſtars, riſe and ſet in Greenland in a manner very different from what they do in the Eaſt Indies, and in both places very different from what they do in England: and as it was natural to attribute the cauſe of this change in the apparent face of the heavens, to the figure of the earth, (for appearances muſt ever anſwer to the form and ſtructure of the things) the nature of this figure was, therefore, one of the firſt objects of inquiry among philoſophers and aſtronomers.

Some of the ſages of antiquity concluded, that the earth muſt neceſſarily be of a ſpherical figure, becauſe that figure was, on many accounts, the moſt convenient for the earth, as an habitable world: they alſo argued, that this figure was the moſt natural, becauſe any body expoſed to forces, which tend to one common center, as is the caſe with the earth, would neceſſarily aſſume a round figure. The aſſent, however, of the modern philoſopher to this truth, was not determined by ſpeculative reaſoning; but on evidence, derived from facts and actual obſervation. From theſe I ſhall ſelect thoſe arguments,

ments, that I think will have the greateſt weight with young minds.

It is known, from the laws of optics and perſpective, that if any body, in all ſituations, and under all circumſtances, projects a circular ſhadow, that body muſt be a globe.

It is alſo known, that eclipſes of the moon are cauſed by the ſhadow of the earth.

And we find, that whether the ſhadow be projected towards the eaſt, or the weſt, the north, or the ſouth, under every circumſtance it is circular; the body, therefore, that caſts the ſhadow, which is the earth, muſt be of a globular figure.

We ſhall obtain another convincing proof of the globular ſhape of the earth, by inquiring in what manner a perſon ſtanding upon the coaſt of the ſea, and waiting for a veſſel which he knows is to arrive, ſees that veſſel. We ſhall find, that he firſt of all, and at the greateſt diſtance, ſees the top of the maſt riſing out of the water; and the appearance is, as if the ſhip was ſwallowed up in the water. As he continues to obſerve the object, more and more of the maſt appears; at length he begins to ſee the top of the deck, and by degrees the whole body of the veſſel. On the other hand, if the ſhip be departing from us, we firſt loſe ſight of the hull, at a greater diſtance the main-ſails diſappear, and at a ſtill greater the top-ſail. But if the

ſurface

surface of the sea were a plane, the body of the ship, being the largest part of it, would be seen first, and from the greatest distance, and the masts would not be visible till it came nearer.

To render this, if possible, still clearer, let us consider two ships meeting at sea, the top-mast of each are the parts first discovered by both, the hull, &c. being concealed by the convexity of the globe which rises between them. The ships may, in this instance, be resembled to two men, who approach each other on the opposite sides of a hill; their heads will be first seen, and gradually, as they approach, the body will come entirely in view. From hence is derived a rational method of estimating the distance of a ship, which is in use among sea-faring people, namely, of observing, HOW LOW THEY CAN BRING HER DOWN, that is to say, the man at the mast-head fixes his eyes on the vessel in sight, and slowly descends by the shrowds, till she becomes no longer visible. The less the distance, the lower he may descend before she disappears. If observations of this kind be made with a telescope, the effect is still more remarkable; as the distance increases or diminishes, the ship in sight will appear to become more and more immersed, or to rise gradually out of the water.

This truth is fully evinced by the following consideration; that ships have sailed round the earth, have gone out to the westward, and have

come home from the eaſtward; or in other words, the ſhips have kept the ſame courſe, and yet returned from the oppoſite ſide into the harbour whence they firſt ſailed. Now we are certain that this could not be the caſe, if the earth were a plane; for then a perſon, who ſhould ſet out for any one point, and go on ſtrait forward, without ſtopping, would be continually going further from the point from which he ſet out. This argument may be much elucidated, by referring the pupil to a terreſtrial globe, on which he may follow the tracks of an Anſon and a Cook round the world.

Fig. 1 and 2, plate II. are illuſtrations of the foregoing principles. Fig. 1, ſhews that if the earth was a plane, the whole of a ſhip would be ſeen at once, however diſtant from the ſpectator, and that whether he was placed at the top or bottom of a hill. From fig. 2, it appears, that the rotundity of the earth, repreſented by the circle A B C, conceals the lower part of the ſhip *d*, while the top-maſt is ſtill viſible; and that it is not till the ſhip comes to e that the whole of it is viſible.

The following remarks evince the ſame truth. Obſerve any ſtar near the northern part of the horizon, and if you travel to the ſouth, it will ſeem to dip farther and farther downwards, till by proceeding, it will deſcend entirely out of ſight. In the mean time, the ſtars to the ſouthward

ward of our traveller will ſeem to riſe higher and higher. The contrary appearances would happen, if he went to the northward. This proves that the earth is not a plane ſurface, but a curve in the direction ſouth and north. By an obſervation nearly ſimilar to this, the traveller may prove the curvature of the earth, in an eaſt and weſt direction.

The globular figure of the earth may be alſo inferred from the operation of levelling, or the art of conveying water from one place to another: for in this proceſs, it is found neceſſary to make an allowance between the true and apparent level; or in other words, for the figure of the earth. For the true level is not a ſtrait line, but a curve which falls below the ſtrait line about eight inches in a mile, four times eight in two miles, nine times eight in three miles, ſixteen times eight in four miles, always increaſing as the ſquare of the diſtance.

What the earth loſes of it's ſphericity by mountains and vallies, is very inconſiderable; the higheſt eminence bearing ſo little proportion to it's bulk, as to be ſcarcely equivalent to the minuteſt protuberance on the ſurface of a lemon.

It is proper, however, to acquaint the young pupil, that though we call our earth a globe, and that when ſpeaking in general terms, it may be conſidered as ſuch; yet in the ſtrictneſs of truth, it muſt be obſerved, that it is not exactly and

perfectly

ſpheroid, flattened a little towards the poles, and ſwelling at the equator; the equatorial diameter being about thirty-four miles longer than the diameter from pole to pole. This difference bears, therefore, too ſmall a portion to the diameter, to be repreſented on globes. M. Caſſini, from Picart's meaſure of a degree, aſſerted, that the earth was an oblong or prolate ſpheroid, flattened at the equator, and protuberant at the poles; while Newton and Huygens, from a conſideration of the known laws and the diurnal motion of the earth, concluded that the figure of the earth was that of an oblate ſpheriod flattened at the poles, protuberant at the equator. To decide this important queſtion, Louis XIV. ordered two degrees of the meridian to be meaſured one under the equator, the other as near the pole as poſſible. For this purpoſe, the Royal Academy of Sciences ſent Meſſ. Maupertuis, Clairaull, Camus, and Le Monnier, to Lapland: they ſet out from France in 1735, and returned in the ſpring of the year 1736, having ſatisfactorily accompliſhed the purpoſe for which they were ſent. Meſſ. Godin, Condamine, and Bouguer were ſent on the ſouthern expedition; to theſe the King of Spain joined Don George Juan, and Don Anthony de Ulloa, who left Europe in the year 1735, and after encountering innumerable hardſhips and difficulties, returned to Europe in diffe-

rent times, and by different ways, in 1744, 1745, 1746. The reſult of this arduous taſk was a complete confirmation of Newton's theoretical inveſtigation. The difference between the equatorial and polar dimenſions, when compared with the earth's ſemidiameter, is but an inconſiderable quantity, amounting in the whole to an elevation of little more than 16½ of 3970; that is, to leſs than a 240th part of the diſtance from the ſurface of the earth to the center. If a meridional ſection of ſuch a ſpheroid were laid down upon paper, the eye would not diſtinguiſh it from a perfect circle.

OF THE DIURNAL MOTION OF THE EARTH.

Though it is this motion which gives us the grateful viciſſitude of day and night, adjuſted to the times of labour and reſt; yet young people generally find ſome difficulty in conceiving that the earth moves; the more ſo, becauſe, in order to allow it, they muſt give up, in a great meaſure, the evidence of their exterior ſenſes, of which the impreſſions are at their age exceeding ſtrong and lively. It will, therefore, be neceſſary for the tutor to prove to them, that they can by no means infer that the earth is at reſt, becauſe it appears ſo, and convince them by a variety of facts, that reaſon was given to correct the fallacies of the ſenſes.

To this end we ſhall here point out ſome inſtances,

ſtances, where apparent motion is produced in a body at reſt, by the real motion of the ſpectator. Let us ſuppoſe a man in a ſhip to be carried along by a briſk gale, in a direction parallel to a ſhore, at no great diſtance from him; while he keeps his eye on the deck, the maſt, the ſails, or any thing about the ſhip; that is to ſay, while he ſees nothing but ſome part of the veſſel on board of which he is, and conſequently every part of which moves with him, he will not perceive that the ſhip moves at all. Let him, after this, look to the ſhore, and he will ſee the houſes, trees, and hills, run from him in a direction contrary to the motion of the veſſel; and ſuppoſing him to have received no previous information on this ſubject, he might naturally conclude, that the apparent motion of theſe bodies was real.

In a ſimilar ſituation to this, we may conceive the inhabitants of the earth; who, in early times, knowing nothing of the true ſtructure or laws of the univerſe, ſaw the ſun, the ſtars, and the planets, riſe and ſet, and perform an apparent revolution about the earth. They had no idea of the motion of the earth, and therefore all this appearance ſeemed reality. But as it is highly reaſonable to ſuppoſe, that as ſoon as the ſlighteſt hint ſhould be given to the man, of the motion of the veſſel, he would begin to form a new opinion, and conceive it to be more rational, that

that ſo ſmall a thing as the ſhip ſhould move, rather than all that part of the earth which was open to his view; ſo, in the ſame manner, no ſooner was an idea formed of the vaſt extent and greatneſs of the univerſe, with reſpect to this earth, than mankind began to conceive it would be more rational that the earth ſhould move, than the whole fabric of the heavens.

By another familiar inſtance, it will be eaſy to ſhew the young pupil, that as the eye does not perceive it's own motion, it always judges from appearances. Let a perſon go into a common windmill, and deſire the miller to turn the mill round, while he is ſitting within it with his eyes fixed on the upright poſt in the center thereof; this poſt, though at reſt, will appear to him to turn round with conſiderable velocity, the real motion of the mill being the cauſe of the apparent motion of the ſwivel poſt. Sea-faring people are furniſhed with various inſtances to illuſtrate this ſubject; thoſe who are buſy in the hold of a ſhip at anchor, cannot by any perception determine whether the ſhip has ſwung round or not by the turn of the tide. When a ſhip firſt gets under way with a light breeze, ſhe may be going at a good rate before thoſe who are between decks can perceive it. Having thus obviated the objections which ariſe from the teſtimony of the ſenſes, we may now proceed to conſider the argu-

arguments which tend more directly to prove the motion of the earth.

All the celeſtial motions will, on this ſuppoſition, be incomparably more ſimple and moderate.

This opinion is much more agreeable to our notions of final cauſes, and our knowledge of the œconomy of nature; for if the earth be at reſt, and the ſtars, &c. move round it once in 24 hours, their velocity muſt be immenſe; and it is certainly more agreeable to reaſon, that one ſingle body, and that one of the ſmalleſt, ſhould revolve on it's own axis in 24 hours, than that the whole univerſe ſhould be carried round it, in the ſame time, with inconceivable velocity.

The rotation of the earth round it's axis is analogous to what is obſerved in the ſun, and moſt of the planets; it being highly probable, that the earth, which is itſelf one of the planets, ſhould have the ſame motion as they have, for producing the ſame effect: and it would be as abſurd in us to contend for the motion of the whole heavens round us in 24 hours, rather than allow a diurnal motion to our globe, as it would be for the inhabitants of Jupiter to inſiſt that our globe, and the whole heavens, muſt revolve round them in ten hours, that all it's parts might ſucceſſively enjoy the light, rather than grant a diurnal motion to their habitation.

All

All the phænomena relative to this ſubject, are as eaſily ſolved on the ſuppoſition of the earth's motion, as on the contrary hypotheſis.

The truth of the foregoing poſition is pleaſingly illuſtrated by the armillary ſphere, which is ſhewn, fig. 2, pl. XIII. The exterior circles repreſent the ſphere of the heaven; within theſe, and in the center of the ſphere, is placed a little globe, ſupported by a ſteel axis. *a* and *b* are two milled nuts. By moving the nut *a*, the ſmall globe may be turned round the ſame way we ſuppoſe our earth to revolve, while the outer part, or ſphere, remains fixed; but if the nut *b* be turned the contrary way, the ſphere will move round the globe, the ſame way as the heavens appear to move. Thus, by this machine, the real motion of the earth round it's axis, within the ſphere of the heavens, or the apparent motion of the heavens round the earth, may be repreſented: and it ſhews, that the reſult of the various problems are the ſame, whether we ſuppoſe the heavens to move round the earth, or the earth to revolve on it's axis.

Beſides the foregoing conſiderations, there are ſeveral arguments to be deduced from the higher parts of aſtronomy, which demonſtrably prove the diurnal motion of the earth.

Definitions.

Before we enter into a further explanation of phænomena, it will be neceſſary to define ſome

of

of the principal circles of the globe. The reader will comprehend more fully these definitions, and attain more accurate ideas of these circles, by placing, while he is reading them, a terrestrial globe, or armillary sphere, before him. It may, however, be necessary to premise, that we are at liberty to suppose as many circles as we please, to be described on the earth; and the plane of any of these to be continued from the earth, until it marks a corresponding circle in the concave sphere of the heavens.

Among these circles, the HORIZON is the most frequently named. Properly speaking, there are two circles called by this name, but distinguished from each other by added epithets, the one being called the SENSIBLE, the other the RATIONAL HORIZON.

In general terms, the HORIZON may be defined to be an imaginary circle, that separates the visible from the invisible part of the heavens.

If a spectator supposes the floor or plane on which he stands, to be extended every way, till it reach the starry heavens, this plane is his SENSIBLE HORIZON.

The RATIONAL HORIZON is a circle, whose plane is parallel to the former, but passing through the center of the earth.

The rational horizon divides the concave sphere of the heavens into equal parts, or hemispheres; the objects that are in the upper hemi-

sphere

ſphere will be viſible; ſuch as are in the lower hemiſphere will be inviſible to the ſpectator.

Though the globe of the earth appears ſo large to thoſe who inhabit it, yet it is ſo minute a ſpeck, when compared to the immenſe ſphere of the heavens, that at that diſtance the planes of the rational and ſenſible horizons coincide; or in other words, the diſtance between them in the ſphere of the heavens, is too ſmall for admeaſurement.

To illuſtrate this, let A B C D, fig. 1, plate III. repreſent the earth; z h n o the ſphere of the ſtarry heaven. If an inhabitant of the earth ſtands upon the point A, his ſenſible horizon is *ſ e*, his rational one h o; the diſtance between the planes of theſe two horizons is A F, the ſemidiameter of the earth, which is meaſured in a great circle upon the ſphere of the heaven, by the angle e F o, or the arc e o; this arch in ſo ſmall a circle, as z h n o, would amount to ſeveral degrees, and conſequently the difference between the ſenſible and the rational horizon would be great enough to be meaſured by obſervation. If we repreſent the ſphere of the heaven by a larger circle, the ſemidiameter of the earth A F meaſured in this circle, will amount to fewer degrees; for the arc E O is leſs than the arc e o; and the larger the ſphere of the heaven is, in proportion to the globe of the earth, the leſs ſenſible is the difference between the two horizons. Now as

the ſphere of the earth is but as a point, when compared to the ſtarry heaven, the difference between the ſenſible and rational horizon will be inſenſible.

From what has been ſaid, it appears that the only diſtinction between the ſenſible and rational horizon, ariſes from the diſtance of the object we are looking at.

The SENSIBLE HORIZON is an imaginary circle, which terminates our view, when the objects we are looking at are upon the earth's ſurface.

The RATIONAL HORIZON is an imaginary circle, which terminates our view, when the objects we are looking at are as remote as the heavenly bodies.

As the rational horizon divides the apparent celeſtial ſphere into two equal hemiſpheres, and ſerves as a boundary, from which to meaſure the elevation or depreſſion of celeſtial objects; thoſe in the upper, or viſible hemiſphere, are ſaid to be high, or elevated, above the horizon; and thoſe in the other hemiſphere are called low, or below the horizon.

The earth being a ſpherical body, the horizon, or limits of our view, muſt change as we change our place; and therefore, every place upon the earth has a different horizon. Thus if a man lives at a, fig. 2, plate III. his horizon is G C: if he lives at b, his horizon is H D: if at c, it is A E. From hence we obtain another proof of the

the ſphericity of the earth; for if it were flat, all the inhabitants thereof would have the ſame horizon.

The point in the heavens, which is directly over the head of a ſpectator, is called the ZENITH.

That point which is directly under his feet, is called the NADIR.

If a man lives at a, fig. 2, plate III. his zenith is A, his nadir E. If he lives at b, his zenith is B, his nadir F; conſequently the zenith and horizon of an obſerver remains fixed in the heavens, ſo long as he continues in the ſame place; but he no ſooner changes his poſition, than the horizon touches the earth in another point, and his zenith anſwers to a different point in the heavens.

The AXIS of the earth, is an imaginary line, conceived to be drawn through the center of the earth, upon which line it's revolutions are made.

The POLES of the earth, are the extremities of it's axis, or thoſe two points on it's ſurface, where it's axes terminate; one of theſe is called the NORTH, and the other the SOUTH POLE. The poles of the heavens, or of the world, are thoſe two points in the heavens, where the axis of the earth, if produced, would terminate; ſo that the north pole of the heavens is exactly over the north pole of the earth, and the ſouth pole of the heavens is directly over the ſouth pole of the earth.

The EQUATOR, is an imaginary circle, which is ſuppoſed to be drawn round the earth's ſurface, in the middle between the two poles. It divides the earth into two equal parts, one of which is called the NORTHERN, the other the SOUTHERN HEMISPHERE.

If we ſuppoſe the plane of the earth's equator to be extended all ways, as far as the heavens, it will mark there a circle, that will divide the heavens into two equal parts; this circle is called ſometimes the EQUINOCTIAL, ſometimes the CELESTIAL EQUATOR.

The MERIDIAN of any place, is a circle ſuppoſed to paſs through that place and the poles of the earth; we may therefore imagine as many meridians as there are places upon the earth, becauſe any place that is ever ſo little to the eaſt or weſt of another place, has a different meridian.

By the foregoing definition, we ſee that the meridian of any place is immoveably fixed to that place, and carried round along with it by the rotation of the earth. The meridian marks upon the plane of the horizon the north and ſouth points.

The circle which the ſun appears to deſcribe every year, in the concave ſphere of the heavens, is called the ECLIPTIC. It is thus denominated, becauſe in all eclipſes the moon is either in or near the plane of it. But as the earth moves round

round the ſun, in the plane of the ecliptic, it is likewiſe the plane of the earth's orbit.

If we conceive a zone, or belt, about ſixteen degrees broad in the concave ſphere of the heaven, with the ecliptic paſſing through the middle of it, this zone is called the ZODIAC. The ſtars in the zodiac were divided by the ancients into twelve equal parts or ſigns, to correſpond with the months of the year; and becauſe the number twelve with them was always expreſſive of fulneſs or completion, it is uſed in that ſenſe in ſacred writ. The ſigns are named, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Piſces.

We may imagine as many circles as we pleaſe drawn on the globe, parallel to the equator, and theſe will decreaſe in their diameter, as they approach nearer the poles. The TROPICS are two leſſer circles of this kind, parallel to the equator, and 23½ degrees diſtant from it; one in the northern hemiſphere, which is called the TROPIC OF CANCER; the other in the ſouthern, which is called the TROPIC OF CAPRICORN. If we conceive the planes of theſe circles expanded, till they reach the ſtarry heaven, the ſun will be ſeen to move in that circle which correſponds to the tropic of cancer on the longeſt ſummer's day, and in that circle which anſwers to the tropic of capricorn on the ſhorteſt winter's day.

The polar circles are two leſſer circles, conceived to be deſcribed at 23½ degrees diſtance from each pole.

The axis of the earth is inclined to the plane of the ecliptic, and makes with it an angle of 66½ degrees; therefore the plane of the earth's equator cannot coincide with the plane of the ecliptic, but theſe two planes make with one another an angle of 23½ degrees.

Of the annual Motion of the Earth.

The foregoing definitions being underſtood, we may now proceed in the deſcription of the phænomena of our ſyſtem. It is owing to the induſtry of modern aſtronomers, that the annual motion of the earth has been fully evinced; for though this motion had been known to, and adopted by many among the ancient philoſophers, yet they were not able to give their opinions that degree of probability, which is attainable from modern diſcoveries, much leſs the evidence ariſing from thoſe demonſtrative proofs of which we are now in poſſeſſion. We ſhall, therefore, enumerate ſome of the reaſons which induce aſtronomers to believe that the earth moves round the ſun, and then explain further the nature of this motion, calculated to afford us the uſeful and delightful variety of the ſeaſons, the mutual allay of immoderate heat

and cold, as alſo for the ſucceſſive growth and recruit of vegetation.

The celeſtial motions become incomparably more ſimple, and free from thoſe looped contortions which muſt be ſuppoſed in the other caſe, and which are not only extremely improbable, but incompatible with what we know of motion.

This opinion is alſo more reaſonable, on account of the extreme minuteneſs of the earth, when compared with the immenſe bulk of the ſun, Jupiter, and Saturn; and there are no known laws of motion, according to which ſo great a body as the ſun can revolve about ſo ſmall a one as the earth.

The ſun is the fountain of light and heat, which it darts through the whole ſyſtem; it ought, therefore, to be in the center, that it's influence may be regularly diffuſed through the whole heavens, and communicated in juſt gradations to the whole ſyſtem.

When we conſider the ſun as the center of the ſyſtem, we find all the bodies moving round it, agreeable to the univerſal laws of gravity; but upon any other conſideration we are left in the dark.

The motion of the earth round the ſun, accords with that general harmony, and univerſal law, which all the other moving bodies in the ſyſtem obſerve, namely, THAT THE SQUARES OF THE PERIODIC TIMES ARE AS THE CUBES OF THE

DISTANCES; but if the ſun moves round the earth, that law is deſtroyed, and the general order of ſymmetry in nature interrupted.

It is inconteſtibly proved by obſervation, a motion having been diſcovered in all the fixed ſtars, which ariſes from a combination of the motion of light with the motion of the earth in it's orbit.

It will be clearly ſhewn in it's place, that Venus and Mercury move round the ſun in orbits that are between it and the earth; that the orbit of the earth is ſituated between that of Venus and Mars; and that the orbits of Mars, Jupiter, &c. are exterior to, and include the other three.

OF THE APPARENT MOTION OF THE SUN, ARISING FROM THE EARTH'S ANNUAL MOTION ROUND IT.

As when a perſon ſails along the ſea coaſt, the ſhore, the villages, and other remarkable places on land, appear to change their ſituation, and to paſs by him; ſo it is in the heavens. To a ſpectator upon the earth, as it moves along it's orbit, or ſails as it were through celeſtial ſpace, the ſun, the planets, and the fixed ſtars, appear to change their places.

Apparent change of place is of two ſorts; the one is that of bodies at reſt, the change of whoſe place depends ſolely on that of the ſpectator; the other is that of bodies in motion, whoſe apparent

parent change of place depends as well on their own motion, as on that of the ſpectator.

We ſhall firſt conſider only that apparent change which takes place in thoſe which are at reſt, and which is owing wholly to the motion of the earth, and ſhew that the ſun, when ſeen from the earth, will appear to move in the ſame manner, whether it revolves round the earth, or whether the earth revolves round the ſun. Let us ſuppoſe the earth at reſt, without any motion of it's own, and let the ſun be ſuppoſed to revolve round it in the orbit A B C D, fig. 1, plate IV. and let E F G H be a circle in the concave ſphere of the ſtarry heavens; as the ſun moves in the order of the letters A B C D in it's orbit, it will appear to a ſpectator on the earth to have deſcribed the circle E F G H. When the ſun is at A, it will appear as if it was among the fixed ſtars that are at E; when it is at B, it will appear among the fixed ſtars at F; when at C, among thoſe at H; and when it is at D, it will appear among the fixed ſtars at G. Indeed, the fixed ſtars and the ſun are not ſeen at the ſame time; but we have ſhewn, that we may tell in what part of the heavens the ſun is, or what fixed ſtars it is near, by knowing thoſe which are oppoſite to it, or come to the ſouth at midnight. Therefore, if we find that any ſet of ſtars, as thoſe at G for inſtance, come to the ſouth at midnight, we may be ſure that they are oppoſite to the ſun; and conſequently, if we could ſee the ſtars in that

part

part of the heaven where the ſun is, we ſhould find them to be thoſe at F.

Secondly, let us ſuppoſe that S is the ſun, that it has no motion of it's own, that it reſts within the orbit A B C D, in which we ſhall now ſuppoſe the earth to move, in the order of the letters A B C D. Upon this ſuppoſition, when the earth is at A, the ſun will appear in that part of the heavens where the ſtars H are; when the earth is at B, the ſun will appear in that part of the heavens where the ſtars G are; when the earth is at C, the ſun will appear in that part of the heavens where the ſtars E are; and as the earth revolves round the ſun, in the orbit A B C D, the ſun will appear to a ſpectator on the earth to deſcribe the circle G H E F.

Thus whether the earth is at reſt, and the ſun revolves in the orbit A B C D; or the ſun is at reſt, and the earth revolves in the ſame orbit, a ſpectator on the earth will ſee the ſun deſcribe the ſame circle E, F G H, in the concave ſphere of the heavens.

Hence if the plane of the earth's orbit be imagined to be extended to the heavens, it would cut the ſtarry firmament in that very circle, in which a ſpectator in the ſun would ſee the earth revolve every year: while an inhabitant of the earth would obſerve the ſun to go through the ſame circle, and in the ſame ſpace of time that the ſolar ſpectator would ſee the earth deſcribe it.

The

The inhabitants of all the other planets will obſerve juſt ſuch motions in the ſun as we do, and for the very ſame reaſons; and the ſun will be ſeen from every planet to deſcribe the ſame circle, and in the ſame ſpace of time, that a ſpectator in the ſun would obſerve the planet to do. For example, an inhabitant of Jupiter would think that the ſun revolved round him, deſcribing a circle in the heavens in the ſpace of twelve years: this circle would not be the ſame with our ecliptic, nor would the ſun appear to paſs through the ſame ſtars which he does to us. On the ſame account, the ſun, ſeen from Saturn, will appear to move in another circle, diſtinct from either of the former; and will not ſeem to finiſh his period in leſs time than thirty years. Now as it is impoſſible that the ſun can have all theſe motions really in itſelf, we may ſafely affirm, that none of them are real, but that they are all apparent, and ariſe from the motions of the reſpective planets.

One phænomenon ariſing from the annual motion of the earth, which has already been ſlightly touched upon, may now be more fully explained; for as from this motion, the ſun appears to move from weſt to eaſt in the heavens, if a ſtar riſes or ſets along with the ſun at any time, it will in the courſe of a few days riſe or ſet before it, becauſe the ſun's apparent place in the heavens will be removed to the eaſtward of that ſtar. Hence thoſe

ſtars

ſtars which at one time of the year ſet with the ſun, and therefore do not appear at all, ſhall at another time of the year riſe when the ſun ſets, and ſhine all the night. And as any one ſtar ſhifts it's place with reſpect to the ſun, and in conſequence of that with reſpect to the hour of the night, ſo do all the reſt. Hence it is that all thoſe ſtars, which at one time of the year appear on any one ſide of the pole ſtar in the evening, ſhall in half a year appear on the contrary ſide thereof.

OF PHÆNOMENA OCCASIONED BY THE ANNUAL AND DIURNAL MOTIONS OF THE EARTH.

Firſt, of thoſe that ariſe from the diurnal motion. As the earth is of a ſpherical figure, that part of it which comes at any time under the confined view of an obſerver, will ſeem to be extended like a plane; and the heavens will appear as a concave ſpherical ſuperficies, divided by the aforeſaid plane into two equal parts,* one of which is viſible, the other concealed from us by the opacity of the earth.

Now the earth, by it's revolution round it's axis, carries the ſpectator and the aforeſaid plane from WEST TO EAST; therefore all thoſe bodies to the eaſt, which could not be ſeen becauſe they were below the plane of the horizon, will become viſible,

* See page 82 of theſe Eſſays.

viſible, or riſe above it, when, by the rotation of the earth, the horizon ſinks as it were below them. On the other hand, the oppoſite part of the plane, towards the weſt, riſing above the ſtars on that ſide, will hide them from the ſpectator, and they will appear to ſet, or go below the horizon.

As the earth, together with the horizon of the ſpectator, continues moving to the eaſt, and about the ſame axis, all ſuch bodies as are ſeparated from the earth, and which do not partake of that motion, will ſeem to move uniformly in the ſame time, but in an oppoſite direction, that is, from EAST TO WEST; excepting the celeſtial poles, which will appear to be at reſt. Therefore, when we ſay, that the whole concave ſphere of the heavens appears to turn round upon the axis of the world, whilſt the earth is performing one rotation round it's own axis, we muſt be underſtood to except the two poles of the world, for theſe do not partake of this apparent motion.

It is, therefore, on account of the revolution of the earth round it's axis, that the ſpectator imagines the whole ſtarry firmament, and every point of the heaven, (excepting the two celeſtial poles) to revolve about the earth from eaſt to weſt every twenty-four hours, each point deſcribing a greater or leſſer circle, as it is more or leſs remote from one of the celeſtial poles.

Although

Although every place on the ſurface of the terraqueous globe is illuminated by all the ſtars which are above the horizon of that place; yet when the ſun is above the horizon, his light is ſo ſtrong, that it quite extinguiſhes the faint light of the ſtars, and produces DAY. When the ſun goes below the horizon, or more properly, when our horizon gets above the ſun, the ſtars give their light, and we are in that ſtate which is called NIGHT.

Now as the earth is an opake ſpherical body, at a great diſtance from the ſun, ONE HALF of it will always be illuminated thereby, while the other half will remain in darkneſs.

The circle which diſtinguiſhes the illuminated face of the earth from the dark ſide, and is the boundary between light and darkneſs, is generally called THE TERMINATOR. A line drawn from the center of the ſun to the center of the earth, is perpendicular to the plane of this circle.

When any point in the globe firſt gets into the enlightened hemiſphere, the ſun is juſt riſen to that part; when it gets half-way, or to it's greateſt diſtance from the terminator, it is then NOON; and when it leaves the enlightened hemiſphere, it is then SUN-SET; but it ſtill enjoys ſome light from the ſun, which is reflected by the atmoſphere, till it gets eighteen degrees beyond the terminator; this glimmering light is called TWILIGHT.

We

We have already ſhewn, that the daily motion of the ſun from eaſt to weſt, is not a real, but an apparent one, which is owing to the rotation of the earth round it's axis. Now if the ſun had no other motion but this apparent one, it would ſeem to go once round the earth, in the time of one complete rotation, or in 23 hours, 56 minutes; which is the caſe with any of the fixed ſtars, and is therefore the length of a SIDERIAL DAY. But the ſun is found to take up a longer time to complete it's apparent revolution; for if it is in the ſouth of any particular place at twelve o'clock at noon to-day, it will not complete an apparent revolution, ſo as to return to the ſouth of that place again, till twelve o'clock at noon on the next day, and conſequently the time of this apparent revolution is twenty-four hours.

Let us endeavour to render this ſubject clearer, by defining in other words the nature of the ſolar and ſiderial day.

The SOLAR DAY, is that ſpace of time which intervenes between the ſun's departing from any one meridian, and it's return to the ſame circle again; which ſpace is alſo called a natural day, or it is the time from the noon of one day to the noon of the next.

The ſiderial day, is the ſpace of time which happens between the departure of a ſtar from, and it's return to the ſame meridian again.

We

We are now to ſhew why theſe days differ in length, or why the time, that the ſun takes up to complete one revolution, is longer than the time that the earth takes to revolve once upon it's axis.

This difference ariſes from the ſun's annual motion. For the ſun does not continue always in the ſame place in the heaven, as the fixed ſtars do: but if it is ſeen at M, fig. 2, pl. IV. one day, near the fixed ſtar R, it will have ſhifted it's place the next day, and will be near to ſome other fixed ſtar L. This motion of the ſun is from weſt to eaſt, and one entire revolution is completed in a year. Suppoſe, therefore, that the ſun, when it is at M, near to the fixed ſtar R, appears in the ſouth of any particular place S; and then imagine the earth to turn once round upon it's axis from weſt to eaſt, or in the direction S T V W, ſo that the place may be returned to the ſame ſituation; after this rotation is completed, the ſtar R will be in the ſouth of the place as before; but the ſun having, in the mean time, moved eaſtwards, and being near to the ſtar L, or to the eaſt of R, will not be in the ſouth of the place S, but to the eaſtward of it: upon this account, the place S muſt move on a little farther, and muſt come to T before it will be even with the ſun again, or before the ſun will appear exactly in the ſouth.

This

This may be illuftrated by an inftance. The two hands of a watch are clofe together, or even with one another at twelve; they both turn round the fame way, but the minute hand turns round in a fhorter time than the hour hand; when the minute hand has completed one rotation, and is come round to twelve, the hour hand will be before it, or will be at one; fo that the minute hand muft move more than once round, in order to overtake the hour hand, and be even with it again.

As this fubject is of fome importance, we fhall endeavour to render it more clear, by placing it in a different point of view: the more fo, as it may accuftom the young pupil to reafon on both hypothefes, namely, the motion of the fun, and that of the earth.

The diameter of the earth's orbit is but a phyfical point, in proportion to the diftance of the ftars; for which reafon, and the earth's uniform motion on it's axis, any given meridian will revolve from any ftar to the fame ftar again, in every abfolute turn of the earth upon it's axis, without the leaft perceptible difference of time being fhewn by a clock which goes exactly true.

If the earth had only a diurnal, without an annual motion, any given meridian would revolve from the fun to the fun again, in the fame quantity of time as from any ftar to the fame ftar again; becaufe the fun would never change his place,

with reſpect to the ſtars. But as the earth advances almoſt a degree eaſtward in it's orbit, in the time that it turns eaſtward round it's axis, whatever ſtar paſſes over the meridian on any day with the ſun, will paſs over the ſame meridian on the next day, when the ſun is almoſt a degree ſhort of it, that is, 3 min. 56 ſeconds ſooner. If the year contained only 360 days, the ſun's apparent place, ſo far as his motion is equable, would change a degree every day, and then the ſiderial days would be juſt four minutes ſhorter than the ſolar.

Let A B C D E F G H, fig. 3, plate IV. be the earth's orbit, in which it goes round the ſun every year, according to the order of the letters, that is, from weſt to eaſt, and turns round it's axis the ſame way, from the ſun to the ſun again in every twenty-four hours. Let S be the ſun, and R a fixed ſtar, at ſuch an immenſe diſtance, that the diameter G C of the earth's orbit bears no ſenſible proportion to that diſtance; N m n the earth in different points of it's orbit. Let N m be any particular meridian of the earth, and N, a given point, or place, lying under that meridian.

When the earth is at A, the ſun S hides the ſtar R, which would always be hid if the earth never moved from A, and conſequently as the earth turns round it's axis, the point N would always come

come round to the ſun and the ſtar at the ſame time.

But when the earth has advanced through an eighth part of it's orbit, or from A to B, it's motion round it's axis will bring the point N an eighth part of a day, or three hours, ſooner to the ſtar than to the ſun. For the ſtar will come to the meridian in the ſame time as though the earth had continued in it's former ſituation at A, but the point N muſt revolve from N to n, before it can have the ſun upon it's meridian. The arc N n being therefore the ſame part of a whole circle, as the arc A B, it is plain that any ſtar which comes to the meridian at noon, with the ſun, when the earth is at A, will come to it at nine o'clock in the forenoon, when the earth is at B.

When the earth has paſſed from A to C, one-fourth part of it's orbit, the point N will have the ſtar upon it's meridian, or at ſix in the morning, ſix hours ſooner than it comes round to the ſun; but the point N muſt revolve ſix hours more, before it has mid-day by the ſun: for now the angle ASD is a right angle, and ſo is NDn; that is, the earth has advanced 90 degrees on it' axis, to carry the point N from the ſtar to the ſun; for the ſtar always comes to the meridian when N m is parallel to RSA; becauſe DS is but a point in reſpect to RS. When the earth is at D, the ſtar comes to the meridian at three in the morning, at E, the earth having gone half round it's

 orbit;

orbit; N points to the ſtar at midnight, it being then directly oppoſite to the ſun; and, therefore, by the earth's diurnal motion, the ſtar comes to the meridian twelve hours before the ſun, and then goes on, till at A it comes to the meridian with the ſun again.

Thus it is plain, that one abſolute revolution of the earth on it's axis (which is always completed when any particular ſtar comes to be parallel to it's ſituation at any time of the day before) never brings the ſame meridian round from the ſun, to the ſun again; but that the earth requires as much more than one turn on it's axis, to finiſh a natural day, as it has gone forward in that time, which, at a mean ſtate, is a 365th part of a circle.

From hence we obtain a method of knowing by the ſtars, whether a clock goes true or not. For if through a ſmall hole in a window-ſhutter, or in a thin plate of metal fixed to a window, we obſerve at what time any ſtar diſappears behind a chimney, or corner of a houſe, at a little diſtance; and if the ſame ſtar diſappears the next night, 3 min. 56 ſeconds, ſooner by the clock; and on the ſecond, 7 minutes, 52 ſeconds ſooner; the third night, 11 minutes, 48 ſeconds ſooner, and ſo on every night; it is an infallible ſign that the machine goes true; otherwiſe it does not, and muſt be regulated accordingly. This method may be depended on to nearly half a ſecond.

OF

Of the Seasons of the Year.

It is our buſineſs under the preſent head to account for the phænomena of the ſeaſons, thoſe grateful viciſſitudes on which ſo much, both of the buſineſs and happineſs of man depends. As the ſeaſons are applied in the hieroglyphic language of the bible, to mark the different ſtages of man's progreſs in virtue, the riſe, meridian glory, decline, and conſummation of the church, or the different diſpenſations of divine goodneſs and truth to man; we do not think the reader will be offended, if we preſent him with a few obſervations on this head, extracted from the works of an elegant moraliſt.

The natural advantages which ariſe from the poſition of the earth which we inhabit, with reſpect to the other planets, afford much employment to mathematical ſpeculation; by which it has been diſcovered, that no other conformation of the ſyſtem could have given ſuch commodious diſtributions of light and heat, or imparted fertility and pleaſure to ſo great a part of a revolving ſphere.

The moraliſt may with equal reaſon obſerve, that our globe ſeems equally fitted for the reſidence of a being, placed here only for a ſhort time, whoſe taſk is to advance himſelf to a higher and happier ſtate of exiſtence, by unremitted vigilance of caution, and activity of virtue. The

duties of man are ſuch as human nature does not willingly perform, and ſuch as thoſe are inclined to delay, who intend ſome time to fulfil them. It was, therefore, neceſſary, that this univerſal reluctance ſhould be counteracted, and the drowſineſs of heſitation awakened into reſolve; that the danger of procraſtination ſhould be always in view, and the fallacies of ſecurity be hourly detected. To this end, all the appearances of nature uniformly conſpire: whatever we ſee on every ſide, reminds us of the lapſe of time, and the flux of life. The day and night ſucceed each other; the rotation of the ſeaſons diverſifies the year; the ſun attains the meridian, declines, and ſets; and the moon every night changes it's form.

The day may be conſidered as an image of the year, and a year as the repreſentation of life. The morning anſwers to the ſpring, and the ſpring to childhood and youth. The noon correſponds to the ſummer, and the ſummer to the ſtrength of manhood. The evening is an emblem of autumn, and autumn of declining life. The night with it's ſilence and darkneſs, ſhews the winter, in which all the powers of vegetation are benumbed; and the winter points out the time when life ſhall ceaſe, with it's hopes and pleaſures.

He that is carried forward, however ſwiftly, by a motion equable and eaſy, perceives not the change

change of place, but by the variation of objects. If the wheel of life, which rolls thus ſilently along, paſſed on through undiſtinguiſhable uniformity, we ſhould never mark it's approaches to the end of the courſe. If one hour were like another; if the paſſages of the ſun did not ſhew it's waſting; if the change of ſeaſons did not impreſs upon us the flight of the year; quantities of duration, equal to days and years, would glide away unobſerved. If the parts of time were not variouſly coloured, we ſhould never diſcern their departure or ſucceſſion; but ſhould live thoughtleſs of the paſt, and careleſs of the future, without will, and perhaps without power, to compare the time which is already loſt, with that which may probably remain.

But the courſe of time is ſo viſibly marked, that it is even obſerved by nations, who have raiſed their minds very little above animal inſtinct. That theſe admonitions of nature may have their due effect; let him that deſires to ſee others happy, make haſte to give while his gift can be enjoyed; and remember, that every moment of delay takes away ſomething from the value of his benefaction. And let him who propoſes his own happineſs, reflect, that while he forms his purpoſe, the day rolls on, and the night cometh, when no man can work.

Before we explain the cauſes of thoſe changes that are termed the ſeaſons of the year, it will be

neceſſary to premiſe a few conſiderations: Firſt, that on account of the immenſe diſtance of the ſun from the earth, the rays which proceed from it may be conſidered as parallel to each other. Secondly, that only one-half of a globe can be illuminated by parallel rays, and therefore only one-half of the earth will be enlightened by the ſun at one time. Thirdly, that we may call the line which divides light from darkneſs, the terminator.

Theſe conſiderations, as well as ſome of the following deductions, will be rendered more clear, by a ſurvey of fig. 1, 2, and 3, pl. VI. where N Æ S Q repreſents the globe of the earth; N 80 S, N 70 S, &c. different meridians interſecting the equator Æ Q at right angles, and paſſing through the poles N and S; T T the terminator; B a braſs ball, to repreſent the ſun, with parallel rays proceeding from it.

In fig. 3, the poles coincide with the terminator.

In fig. 1, the north pole is altogether in the ILLUMINATED hemiſphere, and the ſouth pole in the DARK hemiſphere.

In fig. 2, the ſouthern pole is in the ENLIGHTENED part, and the north pole in the DARK hemiſphere.

It is evident that it is day in any given place on the globe, ſo long as that place continues in the enlightened hemiſphere; but when, by the diurnal

diurnal rotation of the earth on it's axis, it is carried into the dark hemiſphere, it becomes night to that place.

The length of the day and the night depend on the poſition of the terminator, with reſpect to the axis of the earth.

If the poles of the earth be ſituated in the terminator, as in fig. 3, every parallel will be divided into two equal parts; and as the uniform motion of the earth cauſes any given place to deſcribe equal parts of it's parallel in equal times, the day and the night would be equal on every parallel of latitude; that is, all over the globe, except at the poles, where the ſun would neither riſe nor ſet, but continue in the horizon.

But if, as in fig. 1 and 2, the axis be not placed in the plane of the terminator, the terminator will divide the equator into two equal parts, but all the circles parallel to it into unequal parts; thoſe circles that are ſituated towards the enlightened pole, will have a greater part of their circumference in the enlightened than in the dark hemiſphere; while ſimilar parallels toward the other pole will have the greater part of their circumference in the dark hemiſphere. Whence it follows, that the firſt-mentioned parallels will enjoy longer days than nights; and the contrary will happen to the latter, where the days will be the ſhorteſt, and the nights the longeſt; while at the equator, the days

days and nights continue equal. All this is evident from the bare inſpection of the figures; it is alſo obſervable, that the diſproportion is greateſt in the greateſt latitude; and that thoſe places, whoſe diſtance from the pole is leſs than that of the pole from the terminator, muſt enjoy either a conſtant day, or a conſtant night; becauſe they are never carried into the oppoſite hemiſphere by the diurnal rotation of the earth. In this poſition of the axis, the inhabitants on one ſide of the equator may be ſaid to enjoy ſummer, and thoſe on the other ſide winter, with reſpect to each other.

From what has been ſaid, it is plain that the viciſſitudes in the days and nights are occaſioned by the poſition of the terminator, or boundary of light and darkneſs, with the axis of the earth; or in other words, by the different aſpect of the earth with reſpect to the ſun.

We have now only to ſhew what cauſes the changes of poſition in the terminator, which are, 1. The inclination of the earth's axis to the plane of the ecliptic, or orbit in which it moves. 2. That through the whole of it's annual courſe, the axis of the earth preſerves it's poſition, or continues parallel to itſelf; that is, if a line be conceived as drawn parallel to the axis while the earth is in any one point of it's orbit, the axis will in every other poſition of the earth be parallel to the ſaid line.

If

If the axis of the earth were perpendicular to the plane of it's orbit, the equator and the orbit (or ecliptic) would coincide; and as the ſun is always in the plane of the ecliptic, it would in this caſe be always over the equator, as in fig. 3, and the two poles would be in the terminator, and there would be no diverſity in the days and nights, and but one ſeaſon of the year; but as this is not the caſe, we may fairly infer, that the axis of the earth is not perpendicular to the plane of it's orbit.

But if the earth's axis be inclined to the plane of the ecliptic when the earth is in the ſituation repreſented at fig. 1, plate VI. the pole N will be towards the ſun, and the pole S will be turned from it; but juſt the contrary will happen, when the earth, by going half round the ſun, has arrived at the oppoſite point in it's orbit. Hence the ſun will not be always in the equator, but at one time of the year it will appear nearer to one of the poles, and at the oppoſite ſeaſon, it will appear nearer to the other. To this circumſtance the change of ſeaſons is owing; for when the ſun leaves the equator and approaches to one of the poles, it will be ſummer on that ſide of the equator, and when the ſun departs from thence and approaches to the other pole, it will be winter. Thus from the inclination of the axis, each part of the earth enjoys the benefit of ſummer in it's turn; for it is evident, from

what

what has been ſaid already, that when it is winter towards one of the poles, on one ſide the equator, it is ſummer towards the other pole, or on the other ſide of the equator.

To elucidate ſtill further the changes in the ſeaſons, we ſhall beg the reader's attention to the figures in plates V. and VI. which repreſent one of the moſt ſimple inſtruments hitherto contrived for explaining them. Fig. 1, plate V. is the whole of the inſtrument. Fig. 1, 2, and 3, plate VI. two portions of it thus exhibited, in order to give a more diſtinct view of the phænomena.

If we now ſuppoſe the earth to be at Libra, as in fig. 1, plate V. then will the ſun appear to be at the oppoſite point of the ecliptic in Aries, the time of our VERNAL EQUINOX. The terminator will paſs through the poles of the world, and divide every parallel to the equator into two equal parts; conſequently the nocturnal and diurnal arches, or the length of the day and night, will be equal in all places over the world. See this further illuſtrated, fig. 3, plate VI.

But if you conceive the earth by it's annual motion to have moved to Capricorn, the axis keeping parallel to itſelf; the north pole will by this motion have gradually advanced into the enlightened hemiſphere, ſo that the whole northern polar circle will, when it has arrived, be in the illuminated hemiſphere, while the ſouthern pole

pole recedes into darknefs, and all the northern parts will enjoy long days, and this time is called our SUMMER SOLSTICE, while the fouthern parts will have fhort days and winter.

Again, while the earth is defcribing the next quarter of it's orbit, or going from Capricorn through Aquarius and Pifces to Aries, the north pole approaches the terminator in the fame proportion that it before receded from it, and confequently the diurnal arches gradually leffen till it arrives at Aries, when the poles will again coincide with the terminator, and thus caufe the days and nights to be every where equal. This is called the AUTUMNAL EQUINOX.

During the next quarter, or while the earth is going through Taurus and Gemini, the north pole will gradually recede from the light, while the fouthern one advances into it; and the days will fhorten in the northern hemifphere, and lengthen in the fouthern, until the earth is arrived at Cancer, the fun then appearing in Capricorn, when the north pole will be juft as far within the dark as in June it was in the enlightened hemifphere. This time is called the WINTER SOLSTICE. The days every where in the northern hemifphere are now at the fhorteft, and to the fouthward they are at the longeft.

From the winter folftice to the vernal equinox the pole will approach the terminator, and the days will again lengthen in the northern hemifphere,

ſphere, and at the inſtant in which the axis again coincides with the pole, the natural year, conſiſting of 365 days, 5 hours, 48½ minutes, is finiſhed.

The pupil will obſerve, by conſidering the inſtrument, that during the whole revolution of the earth, one-half of the equator is always in the light, and the other half in darkneſs; and conſequently, that under the equator the days and nights are always of an equal length.

While the earth is going from Libra to Aries, the north pole is conſtantly illuminated, and the ſouth pole all the while in darkneſs; and for the other half of the year in a contrary ſtate.

It is eaſy to perceive, by the foregoing explanation, that the inhabitants of the ſouthern hemiſphere have the ſame viciſſitudes, though not at the ſame time, it being winter in one hemiſphere while it is ſummer in the other.

There is ſtill, however, one circumſtance to be conſidered, namely, the daily apparent change in the ſun's declination; but this will be eaſily conceived, by attending to fig. 1, 2, and 3, pl. VI. and conceiving a line to be drawn from the center of the ſun to the center of the earth, in each ſituation. This line may be called the central ſolar ray. About the 21ſt of December, when the earth is in Cancer, this ray will terminate or fall upon the ſouthern tropic, or the tropic of Capricorn; and conſequently, by the earth's rotation

tation round her axis, the inhabitants of every part of this circle will ſucceſſively have the ſun in their zenith; or in other words, he will be vertical to them that day at noon, as the ſun appears that day to be carried round in the tropic of Capricorn.

About the 20th of March, the earth is at Libra, and the ſun will then appear in Aries; the central ſolar ray terminates upon the ſurface of the earth, in the equator, as at fig. 3; and therefore the ſun appears to be carried round in the celeſtial equator, and is ſucceſſively vertical to thoſe who live under that circle.

About the 21ſt of June, when the earth is in Capricorn, the central ſolar ray terminates on the ſurface of the earth, in the northern tropic, as at fig. 2; and for that day the ſun appears to be carried round in the tropic of Cancer, and is vertical to thoſe who live under that circle. About the 22nd of September, the earth is in Aries, and the ſun in Libra, and the central ſolar ray again terminates at the equator; conſequently the ſun again appears in the celeſtial equator, and is vertical to thoſe who live under it.

We have ſeen, that as the ſun moves in the ecliptic, from the vernal equinox to the tropic of Cancer, it gets to the north of the equator, or it's declination towards our pole increaſes. Therefore, from the vernal equinox, when the days and nights are equal, till the ſun comes to the tropic

tropic of Cancer, our days lengthen, and our nights ſhorten; but when the ſun comes to the tropic of Cancer, it is then in it's utmoſt northern limit, and returns in the ecliptic to the equator again. During this return of the ſun, it's declination towards our pole decreaſes, and conſequently the days decreaſe, and the nights increaſe, till the ſun is arrived in the equator again, and is in the autumnal equinoctial point, when the days and nights will again be equal. As the ſun moves from thence towards the tropic of Capricorn, it gets to the ſouth of the equator; or it's declination towards the ſouth pole increaſes. Therefore, at that time of year, our days ſhorten, and our nights lengthen, till the ſun arrives at the tropic of Capricorn; but when the ſun is arrived there, it is then at it's utmoſt ſouthern limit, and returns in the ecliptic to the equator again. During this return, it's diſtance from our pole leſſens, and conſequently the days will lengthen, as the nights will ſhorten, till they become equal, when the ſun is come round to the vernal equinoctial point.

Our ſummer is nearly eight days longer than the winter. By ſummer is meant here the time that paſſes between the vernal and autumnal equinoxes; by winter, the time between the autumnal and vernal equinox. The ecliptic is divided into ſix northern, and ſix ſouthern ſigns, and interſects the equator at the firſt of Aries, and

and the firſt of Libra. In our ſummer, the ſun's apparent motion is through the ſix northern, and our winter through the ſix ſouthern ſigns; yet the ſun is 186 days, 11 hours, 51 minutes, in paſſing through the ſix firſt; and only 178 days, 17 hours, 58 minutes, in paſſing through the ſix laſt. Their difference, 7 days, 17 hours, 53 minutes, is the length of time by which our ſummer exceeds the winter.

In fig. 1, plate VII. A B C D repreſents the earth's orbit; S the ſun in one of it's foci; when the earth is at B, the ſun appears at H, in the firſt point of Aries; and whilſt the earth moves from B through C to D, the ſun appears to run through the ſix northern ſigns, from ♈ through ♋ to ♎ at F. When the earth is at D, the ſun appears at F, in the firſt point of Libra; and as the earth moves from D through A to B, the ſun appears to move through the ſix ſouthern ſigns, from ♎ through ♑ to Aries at H.

Hence the line F H, drawn from the firſt point of Aries through the ſun at S, to the firſt point of ♎, divides the ecliptic into two equal parts; but the ſame line divides the earth's elliptical orbit into two unequal parts. The greater part B C D is that which the earth deſcribes in the ſummer, while the ſun appears in the northern ſigns. The leſſer part is D A B, which the earth deſcribes in winter, while the ſun appears in the ſouthern ſigns. C the earth's aphelion, where it

moves sloweſt, is in the greater part; A it's perihelion, is in the leſſer part, where the ſun moves faſteſt.

There are, therefore, two reaſons why our ſummer is longer than our winter; firſt, becauſe the ſun continues in the northern ſigns, while the earth is deſcribing the greater part of it's orbit; and ſecondly, becauſe the ſun's apparent motion is ſlower while it appears in the northern ſigns, than whilſt it appears in the ſouthern ones.

The ſun's apparent diameter is greater in our winter than in ſummer, becauſe the earth is nearer to the ſun when at A in the winter, than it is when at C in the ſummer. The ſun's apparent diameter, in winter, is 32 min. 47 ſeconds; in ſummer, 31 min. 40 ſeconds.

But if the earth is farther from the ſun in ſummer than in winter, it may be aſked, why our winters are ſo much colder than our ſummers. To this it may be anſwered, that our ſummer is hotter than the winter, firſt, on account of the greater height to which the ſun riſes above our horizon in the ſummer; ſecondly, the greater length of the days. The ſun is much higher at noon in ſummer than in winter, and conſequently, as it's rays in ſummer are leſs oblique than in winter, more of them will fall upon the ſurface of the earth. In the ſummer, the days are very long, and the nights very ſhort; therefore the earth and air are heated by the ſun in the day-

time,

time, more than they are cooled in the night; and upon this account, the heat will keep increaſing in the ſummer, and for the ſame reaſon will decreaſe in winter, when the nights lengthen.

We ſhould exceed the limits of this Eſſay, were we to inquire into the ſeveral concurring cauſes of the temperatures that obtain in various climates; it may be ſufficient, therefore, to obſerve what a remarkable proviſion is made in the world, and the ſeveral parts of it, to keep up a perpetual change in the degrees of heat ad cold. Theſe two are antagoniſts, or as Lord Bacon calls them, THE VERY HANDS OF NATURE WITH WHICH SHE CHIEFLY WORKETH, the one expanding, the other contracting bodies, ſo as to maintain an oſcillatory motion in all their parts; and ſo ſerviceable are theſe changes in the natural world, that they are promoted every year, every hour, every moment. From the oblique poſition of the ecliptic, the earth continually preſents a different face to the ſun, and never receives his rays two days together in the ſame direction. In the day and night, the differences are ſo obvious, that they need not be mentioned, though they are moſt remarkable in thoſe climates, where the ſun at his ſetting makes the greateſt angle with the horizon. Every hour of the day, the heat varies with the ſun's altitude, is altered by the interpoſition of clouds, and the action of winds; and there is little room to doubt, but

what the various changes that thus take place, concur in producing many of the ſmaller and greater phænomena of nature.

Be this however as it may, it is certain that the various irregularities and intemperature of the elements, which ſeem to deſtroy nature in one ſeaſon, ſerve to revive it in another: the immoderate heats of ſummer, and the exceſſive cold of winter, prepare the beauties of the ſpring, and the rich fruits of autumn. Theſe viciſſitudes, which ſeem to ſuperficial minds the effects of a fortuitous concourſe of irregular cauſes, are regulated according to weight and meaſure by that ſovereign wiſdom, who weighs the earth as a grain of ſand, the ſea as a drop of water.

On some Appearances which depend on the Circles of the Heavens, and the Position of the Observer in Respect of them.

For the more eaſy underſtanding of theſe phænomena, it will be neceſſary to premiſe two obſervations.

1. That the inclination of an axis, or orbit, is merely relative, becauſe we compare it with ſome other axis, or orbit, which is not inclined at all. Thus our horizon being level to us, whatever place of the earth we are upon, we conſider it as having no inclination; and yet, if we travel 90 degrees from that place, we ſhall then

have

have an horizon perpendicular to the former, but it will ſtill be level to us.

2. That half of the heavens are viſible to an inhabitant on any part of the earth.

Of a parallel Sphere.

An inhabitant of the earth, who lives at either of the poles, has one of the celeſtial poles in his zenith, or directly over his head; the other in his nadir, or directly under his feet. The celeſtial equator will coincide with the horizon; and as the polar circles, the tropics, and all the circles of daily motion, are parallel to the equator, they will alſo be parallel to the horizon.

It is from this poſition of the circles of the ſphere, in reſpect to the horizon of a perſon who lives at either pole, that he is ſaid to live in a parallel sphere.

As all the circles of daily motion are parallel to the equator, it follows, that all the heavenly bodies, to an inhabitant at the pole, are carried round by their apparent motion, in circles which are parallel to the horizon; (thus the ſun when above the horizon, appears to revolve in a circle parallel to it, and at an altitude equal to his diſtance from the equator) and conſequently this motion can never make thoſe riſe, which move in the circles below the horizon, nor thoſe ſet which move above it.

 Hence,

Hence, alſo, an inhabitant at the north pole has the ſun above his horizon, and therefore perpetual day all the time the ſun is on the north ſide of the equator; that is, for ſix months together. But the ſun is below his horizon, and it is night with him all the time the ſun is on the ſouth ſide of the equator, which is alſo for ſix months; or, in other words, the ſun will be ſeen for half a year, and then it will be day; and it will be hidden for half a year, and then it will be night.

OF A RIGHT SPHERE.

If an obſerver be ſituated under the equator, he will have the celeſtial poles in his horizon, and the celeſtial equator over his head, and at right angles with his horizon: the other circles of daily motion being parallel to the equator, are alſo perpendicular, or at right angles with his horizon; therefore, in a right ſphere the riſing and ſetting of the ſun is in circles that make right angles with the horizon. It is from this poſition of theſe circles that he is ſaid to live in a RIGHT SPHERE.

In a right ſphere, the equator, and every parallel to it, is divided into two equal parts by the horizon, one half being above, the other half below it; there is, therefore, a perpetual equinox under the equator, that is, the days and nights are equal to one another at all times of the

year, each day being 12 hours long, and every night of the ſame length.

Of an oblique Sphere.

In all other poſitions of the ſphere, except thoſe already deſcribed, the equator, and the circles parallel to it, are inclined to the horizon. In this caſe, the poſition of the ſphere is ſaid to be OBLIQUE. This poſition agrees with all thoſe people who live neither under the pole, nor under the equator. One of the poles is elevated above the horizon, the other is depreſſed beneath it, and the equator is inclined to the horizon.

In plate XIV. fig. 1, the terreſtrial globe is in the poſition of the oblique ſphere.

It is evident, that in this ſituation, all the parallels to the equator are divided by the horizon into two unequal parts, but the equator into two equal parts; conſequently the day and night are never equal to an inhabitant in an oblique ſphere, but when the ſun is in the equator, that is, twice a year, on the 20th of March, and the 22d of September. All the reſt of the year the days are either longer or ſhorter than the nights; and the ſun, which always appears to move in the ecliptic, deſcribes one of the parallels to the equator, which are all cut by the horizon into two unequal parts. On the northern ſide of the equator, the days are longer than the nights, as long as the ſun is on the north ſide of the equator;

but the nights are longer than the days, when the fun is to the fouth of the equator.

The portion of the parallels above the horizon is greater in proportion as they are nearer the elevated pole; but when the diftance of the parallel from the pole becomes lefs than the elevation of the pole, then that parallel, and all thofe which are included within it, are wholly above the horizon, no part of them ever fetting or paffing under it. The contrary happens in the parallels that are fituated towards the depreffed pole, a fmaller portion of thefe being above the horizon, and the greater part lying under it. Thofe parallels which are nearer the depreffed pole, than the elevation of the pole, or latitude of the place, remain perpetually (together with the ftars included within them) under the horizon, and are never vifible to us.

In an oblique fphere there is one parallel which is as far diftant from the elevated pole, as the place is from the equator. This parallel is called the circle of PERPETUAL APPARITION, or the largeft of all thofe which conftantly appear; the ftars included within it never either rife or fet, though they are at times more elevated above the horizon than at others. Towards the other pole there is another circle, oppofite to this, which is the circle of PERPETUAL OCCULTATION. All the ftars that are contained within this, never

never riſe, but lie hid under the horizon, and are never ſeen.

AN EXPLANATION OF THE PHÆNOMENA WHICH ARISE FROM THE MOTION OF THE EARTH, AND OF THE INFERIOR PLANETS, MERCURY AND VENUS.

It will be neceſſary in this place to define more exactly ſome words which have been ſlightly explained before, and recall the reader's attention to ſome definitions that have been already given; and it is preſumed, that theſe repetitions will not be an object of complaint, becauſe they will anſwer the beneficial purpoſe of grounding the reader more firmly in the knowledge of the ſcience, to which this eſſay is intended as an introduction.

When two planets are ſeen together in the ſame ſign of the zodiac, and equally advanced therein, they are ſaid to be in CONJUNCTION. But when they are in oppoſite ſigns of the zodiac, they are ſaid to be in OPPOSITION. Thus a planet is ſaid to be in oppoſition to the ſun, when the earth is between the ſun and the planets.

The elongation of a planet is it's apparent diſtance from the ſun. When a planet is in conjunction with the ſun, it has no elongation; when in oppoſition, it's elongation is 180 degrees.

The NODES OF A PLANET'S ORBIT are thoſe two points where the orbit cuts the plane of the ecliptic. We before obſerved, that the orbits of all

the planets are inclined to the plane of the ecliptic, and confequently crofs this plane. In fig. 3, plate III. A B C D is the plane of the ecliptic; E B F D is the orbit of a planet, in which the points B and D are the two nodes.

The LINE OF THE NODES is a line B D, fuppofed to be drawn through the fun from one node to the other. The LIMITS OF A PLANET'S ORBIT are two points in the middle between the two nodes. The point E is called the greateft northern limit, F the greateft fouthern limit.

The greateft diftance of the earth, or of any planet from the fun, is called it's APHELION, or higher apfis; it's leaft diftance is called the PERIHELION, or lower apfis.

Thus in fig. 4, plate III. A is the place of the aphelion, P that of the perihelion.

The axis, P A, fig. 4, of any planet's ellipfis, is called the LINE OF THE APSIDES: the extreme points of it's fhorteft diameter T V are the places of it's mean diftance from the fun; and S T, or S V, the line of it's mean diftance.

When a planet moves according to the order of the figns, it's motion is faid to be DIRECT, or IN CONSEQUENTIA; but when it's motion is contrary to the order of the figns, it is faid to be RETROGRADE, or IN ANTECEDENTIA.

The place in the ftarry heavens that any planet appears in, when feen from the center of the earth, is called it's GEOCENTRIC PLACE. The place

place where it would be ſeen in the celeſtial ſphere, by an obſerver ſuppoſed to be in the ſun, is called it's HELIOCENTRIC PLACE.

OF THE MOTIONS OF THE INFERIOR PLANETS, VENUS AND MERCURY.

There are two different ſituations, in which an inferior planet will appear in conjunction with the ſun; one when the planet is between the ſun and the earth, the other when the ſun is between the earth and the planet. Let A, fig. 2, plate VII. be the earth in it's orbit, E the place of Venus in her orbit EHG, S the ſun, FVPQRTD an arc in the ſtarry heavens. In this ſituation the ſun and Venus are on the ſame ſide of the earth, and will appear in the ſame point of the heavens, ſo as to be in conjunction. If the earth is at A, and Venus at G, they will alſo appear to be in conjunction.

If the earth is at A, the ſun at S, the planet at E, nearer to the earth than the ſun, it is called it's INFERIOR CONJUNCTION. But if the earth is at A, and the planet at G, farther from the earth than the ſun, this is called the SUPERIOR CONJUNCTION of the planet.

If an inferior planet is at E, the earth at A, and the ſun at S, the elongation is nothing, the planet being then in it's inferior conjunction. As the planet moves from E to y, it's elongation increaſes; for when it is at y, it appears in the line

A y P,

A y P, while the ſun appears in the line A S Q; ſo that P A Q will be it's elongation. When the planet is arrived at x, it appears in the line A x V, which is a tangent to it's orbit, and then it's elongation is V A Q, which is the greateſt that can be on that ſide the ſun; for after this, the elongation decreaſes. When the planet is at K, it's elongation is P A Q; when at G, it is nothing, becauſe it is then in it's ſuperior conjunction; as the planet moves on from G, it's elongation again increaſes; for when it comes to C, it appears in the line A C R, and it's elongation is R A Q. When the planet comes to H, a line drawn from the earth through the planet is a tangent to the orbit, and the elongation is T A Q, the greateſt it can have when it is on the other ſide of the ſun; for after this, the elongation again decreaſes.

Hence it is clear, that the inferior planets can never appear far from the ſun, but muſt always accompany it in it's apparent motion through the ecliptic. When we ſee either Venus or Mercury, it is either in an evening, in the weſt, ſoon after the ſun has ſet; or in a morning, a little before the ſun riſes. Venus is indeed bright enough ſometimes to be ſeen in the day-time, but then ſhe is never far from the ſun. The greateſt elongation of Venus is about 40, and of Mercury about 33 degrees.

If

If the earth is at A, fig. 2, plate VII. when Venus appears in any part of the arc E x G, ſhe is weſtward from the ſun, and therefore riſes before him in the morning, and is called the MORNING STAR. When ſhe appears any-where in the arc G H E, ſhe is eaſtward from the ſun, and therefore ſets after him; is ſeen in the evening, and is then the EVENING STAR.

From the apparent motions of the inferior planets, we derive an argument to prove the falſity of the Ptolemaic ſyſtem. If the earth was within the orbit of Venus, as the Ptolemaic ſyſtem ſuppoſes, ſhe might be ſometimes on one ſide of the earth, whilſt the ſun is on the oppoſite ſide; or Venus might be ſometimes in oppoſition to the ſun; but Venus is never ſeen in oppoſition. Therefore the earth is on the outſide of the orbit of Venus, and conſequently the Ptolemaic ſyſtem is not true. The ſame is alſo true of Mercury. But this, and ſome other circumſtances relative to the motions of theſe planets, will be better underſtood by a planetarium than by any diagram.

We have now to explain, WHY THE INFERIOR PLANETS APPEAR TO MOVE SOMETIMES IN ONE DIRECTION, SOMETIMES IN THE CONTRARY ORDER, AND AT OTHER TIMES TO BE STATIONARY. This is eaſily done on the Copernican ſyſtem, it being the natural reſult of the reſpective ſituations and motions of the earth and theſe planets. But on the Ptolemaic ſyſtem it is inexplicable, without

calling

calling in the aid of a very complicated hypothesis.

When the inferior planets are paffing from their greateft elongation, on one fide of the fun, through their fuperior conjunction, to their greateft elongation on the other fide, their motion, as viewed from the earth, is direct. In order to explain this propofition, we fhall firft fuppofe the earth to be at reft at A, fig. 2, pl. VII. and correct this fuppofition afterwards, by fhewing that the apparent motion of Venus, or Mercury, feen from the earth, is the fame in this refpect, whether the earth moves in it's orbit, or refts at A.

The propofition to be explained is this: that as Venus, for inftance, moves from x, it's greateft elongation on one fide of the fun, through G it's fuperior conjunction, to H it's greateft elongation on the other fide, it will appear to a fpectator upon the earth, to move from weft to eaft according to the order of the figns; that is, it's geocentric motion will be direct.

The planets move round the fun from weft to eaft, and confequently if there was a fpectator at the fun, they would appear to him to move through the zodiac, according to the order of the figns; or in other words, the heliocentric motion of Venus is direct. Now if the fun and the earth A, are both on the fame fide of the planet, a fpectator at the earth is in the fame fituation with

with reſpect to the planet and it's motion, as if he had been at the ſun: for whilſt the planet is moving from x, through G to H, a ſpectator either at A or S is on the concave ſide of the planet's orbit; and conſequently the planet will appear to move in the ſame manner from either; but the apparent motion of the planet, when ſeen from the ſun, is direct, and conſequently it's motion, when ſeen from the earth, will alſo be direct.

When Venus is at x, it appears to a ſpectator on the earth at A, to be in the line A x V, or is ſeen among the ſtars at V; when Venus has moved to K, it is ſeen among the fixed ſtars at P; when it has moved to G, it is in it's ſuperior conjunction; when it has moved to C, it appears among the fixed ſtars at R; and when it is come to K, it appears among the fixed ſtars at T. Thus whilſt Venus has moved in it's orbit from x, it's greateſt elongation on one ſide of the ſun, through G it's ſuperior conjunction, to H it's greateſt elongation on the other ſide, it appears to have deſcribed the arc V P Q R T in the concave ſphere of the heavens; but the letters x K G C H lie from weſt to eaſt, becauſe they lie in the ſame direction that the planet moves round the ſun; and the letters V P Q R T lie in the ſame direction with x K G C H. Therefore, as the planet ſeems to a ſpectator on the earth, to deſcribe the arc V P Q R T, it's apparent motion,

tion, ſeen from the earth, is direct, or from weſt to eaſt.

As the inferior planets move from their greateſt elongation on one ſide of the ſun, through their inferior conjunction, to their greateſt elongation on the other ſide, their geocentric motion is RETROGRADE.

Whilſt Venus, for inſtance, is moving from it's greateſt elongation H, plate VII. fig. 3, through it's inferior conjunction E, to it's other greateſt elongation x, it appears to a ſpectator upon the earth at A, to move backwards, or from eaſt to weſt, contrary to the order of the ſigns.

A ſpectator at the ſun is on the concave ſide of the planet's orbit. But whilſt Venus is moving from it's greateſt elongation H on one ſide, through E it's inferior conjunction, to x it's greateſt elongation on the other ſide, a ſpectator upon the earth is on the convex ſide of it's orbit.

Therefore, if a ſpectator at the ſun S would ſee the planet move one way, a ſpectator at the earth A will ſee it move the contrary way; or the geocentric motion will be contrary to it's heliocentric motion, and therefore retrograde; for as ſeen from the ſun, it's motion is always direct.

That two ſpectators, one at the earth, the other at the ſun, as they are on contrary ſides of the arc H E x, will ſee the planet apparently move contrary ways, may be rendered more plain

by

by the following familiar confideration. If two men ftand with their faces towards each other, and a ball is rolled along upon the ground, this ball will move from the right hand of one of the men towards his left, and from the left hand of the other towards his right. In like manner, if one man is at the earth A, and the other at the fun S, then whilft the planet is defcribing the arc H e x which is between them, it will appear to move from the right hand of the man at S towards his left, and from the left hand of the man at A towards his right.

Whilft the motion of Venus is direct, or while it is defcribing the arc x G H, it appears to move from V to T, among the fixed ftars. But after it has been carried in it's orbit from H to Q, it appears in the line A z R, and is feen among the fixed ftars at R. When it comes to E, it appears at Q; and when at y, it's apparent place in the heavens is at P. Thus as the planet paffes from it's greateft elongation H on one fide of the fun, through it's inferior conjunction E, to it's greateft elongation x on the other fide, it apparently runs back from T to V.

Venus is ftationary, or has no apparent motion for fome time, when it is at it's greateft elongation; that is, when it is at H or x, and it's apparent place is either at T or V.

I When

When either of the inferior planets, Venus for inftance, is at it's greateft elongation H or x, a line drawn from the earth through the planet, as A H T, or A x V, is a tangent to the orbit. Now though a right line touches a circle but in one point, yet fome part of the circle greater than a point is fo near to the tangent, as not to be diftinguifhed from it. Thus the arc b d fo nearly coincides with the tangent A H T, that a fpectator's eye placed at A, could not diftinguifh the tangent from this part of the curve. Confequently, while the planet is defcribing this arc, no other change will be made in it's geocentric place, that if it was to move in the tangent.

But the geocentric place of the planet would not be altered, if the planet was to move in the tangent. For if it was to move from T towards A, or from A to V, the apparent place of it in the heavens would in one cafe be at T, in the other cafe at V. Therefore, while the planet is at it's greateft elongation, and is defcribing a fmall arc in it's orbit, that nearly coincides with the tangent, it's geocentric place does not alter, but it appears to continue for fome time in the fame part of the heavens, or is ftationary.

We have hitherto fuppofed the earth to be at reft, and upon that fuppofition have explained the progrefs and regrefs, the conjunctions and ftations of the inferior planets. If this fuppofition was true, V T, or the arc which the planet

at

at any time deſcribes in it's progreſs, and T V, the arc which it deſcribes in it's regreſs, would always be in the ſame part of the heavens. The planet, when in conjunction, would always appear at Q among the ſame fixed ſtars; and at it's elongation, or when it is ſtationary, it would always appear among the ſame fixed ſtars T on one ſide of the ſun, and at V on the other ſide.

But this ſuppoſition is not true; for the earth revolves in it's orbit A B O round the ſun. Now if the earth is at A, the time of either conjunction, the planet at this conjunction would appear among the fixed ſtars at Q, and the arcs of the greateſt elongation Q V and Q T, would be on each ſide of thoſe ſtars. But if the earth is at B, at the time of either of the conjunctions, then at the time of this conjunction, the planet will appear in the line B S T, and be ſeen among the fixed ſtars at T, and the arcs of the greateſt elongation will be on each ſide of theſe ſtars, that is, the conjunctions and elongations will happen in a different part of the heavens, when the earth is at B, from what they happen when the earth is at A. In other reſpects, the foregoing phænomena will be much the ſame, notwithſtanding the motion of the earth, only the planet will be more direct in the fartheſt part of the orbit, and leſs retrograde in the neareſt.

The inferior planets always appear very near the ſun; but by the motion of the earth in it's

orbit, the ſun appears in different parts of the heavens, in different times of the year. Therefore the inferior planets, as they are always very near the ſun, will alſo appear in different parts of the heavens, at different times of the year. And conſequently their conjunctions and greateſt elongations will ſometimes happen when they are in one part of the heavens, and ſometimes when they are in another part. Venus, ſeen from the earth, will appear to vibrate in an arc V T, half of which is on one ſide of the ſun's apparent place, and half on the other ſide.

When an inferior planet, viewed from a ſuperior, moves apparently retrograde, the ſuperior planet has alſo an apparently retrograde motion.

When a ſuperior planet, viewed from an inferior, appears ſtationary, the inferior planet viewed at the ſame time from the ſuperior, is alſo ſtationary.

There is alſo another particular to be taken notice of, with regard to the apparent motion of the inferior planets, viz. that they do not ſeem to deſcribe the ecliptic in the heavens as the ſun does, but are obſerved to be ſometimes above, and ſometimes below it. The reaſon of this is, that their orbits are inclined to the plane of the earth's, having one half above it, and the other below it, on which acount they interſect the plane of the ecliptic, in a plane that paſſes through the center of the ſun; this line is called the line of

of the nodes. Thefe planets, therefore, never appear in the ecliptic, except when they are in their nodes: in all other parts of their orbit they feem to be more or lefs diftant from it, according as they are fituated with refpect to them and the earth.

The diftance of a planet from the ecliptic, as it would appear if feen from the center of the earth, is called it's GEOCENTRIC LATITUDE; as it would appear from the center of the fun, is called it's HELIOCENTRIC LATITUDE.

OF THE SUPERIOR PLANETS.

We have already obferved, that the greateft elongation of either of the inferior planets is lefs than 90°, or a quarter of a circle; fo that they are never far from the fun, but conftantly attend it. But the fuperior planets do not always accompany the fun, as we have fhewn that the inferior ones do; they are indeed fometimes in conjunction with it, but then they are alfo fometimes in oppofition to, or 180° from it.

Let S, fig. 3, plate VII. be the fun; A B C D the orbit of any fuperior planet, Mars, for inftance; E F G the earth's orbit. If the earth be at E, the fun at S, and the planet at D, the fun and the planet will be both on the fame fide of the earth; and confequently the planet will appear in conjunction with the fun. But as the orbit of the earth is between the fun and the

orbit of the ſuperior planet, it is poſſible for the earth to be between the ſun and the planet, and conſequently for the planet and the ſun to be on oppoſite ſides of the earth, or the planet to be in oppoſition; thus, if when the earth is at E, Mars be at A, he is then in oppoſition to the ſun.

A ſuperior planet is in quadrature with the ſun, when it's geocentric place is 90° from the geocentric place of the ſun; thus if the earth be at E, and Mars at B or C, he is in quadrature with the ſun; for the lines A E, E B, form a right angle, as do alſo the lines E A, E C.

As the earth goes round the ſun in leſs time, and in a leſs orbit than any of the ſuperior planets, it will not be amiſs to ſuppoſe a ſuperior planet to ſtand ſtill in ſome part of it's orbit, while the earth goes once round the ſun in her's, and conſider the appearances the planets would then have, which are theſe: 1. While the earth is in her moſt diſtant ſemicircle, the apparent motion of the planet would be direct. 2. While the earth is in her neareſt ſemicircle, the planet would be retrograde. 3. While the earth is near the points of contact of a line drawn from the planet, ſo as to be a tangent to the earth's orbit, the planet would be ſtationary.

To illuſtrate this, let A B C D E F G H, plate VIII. fig. 1, be the orbit of the earth, S the ſun, P Q O V the orbit of Mars, L M N T an arc

arc of the ecliptic. Let us ſuppoſe the planet Mars to continue at P, while the earth goes round in her orbit, according to the order of the letters A B C, &c. A B C D E F G H may be conſidered as ſo many ſtations, from whence an inhabitant of the earth would view Mars at different times of the year; and if ſtrait lines be drawn from each of theſe ſtations, through Mars at P, and continued to the ecliptic, they will point out the apparent place of Mars, at theſe different ſtations.

Thus ſuppoſing the earth at A, the planet will be ſeen among the ſtars at L; when the earth is arrived at B, the planet will appear at M; and in the ſame manner when at C D and E, it will be ſeen among the ſtars at N R T; therefore, while the earth moves over the large part of the orbit A B C D E, the planet will have an apparent motion from L to T, and this motion is from weſt to eaſt, or the ſame way with the earth; and the planet is ſaid to move direct, or according to the order of the ſigns. When the earth is near to A and E, the point of contact of the tangent to the earth's orbit, the planet will be ſtationary for a ſhort ſpace of time.

When the earth moves from E to H, the planet ſeems to return from T to N; and while it moves from H to A, it will be retrograde to L, where it will again be ſtationary: and ſince the part of the orbit which the earth deſcribes in

paſſing from A to E, is much greater than the part E H P, though the ſpace T L which the planet deſcribes in direct and retrograde motion is the ſame, the direct motion from L to T muſt be much ſlower than the retrograde motion from T to L.

When the earth is at C, a line drawn from C through S and P to the ecliptic, ſhews that Mars is then in conjunction with the ſun. But when the earth is at H, a line drawn from H through P, and continued to the ecliptic, would terminate in a point oppoſite to S; therefore in this ſituation Mars would be in oppoſition to the ſun. Thus it appears that the motion of Mars is direct when in conjunction, and retrograde when in oppoſition.

The retrograde motions of the ſuperior planets happen oftener, the ſlower their motions are; as the retrograde motions of the inferior planets happen oftener, the ſwifter their angular motions. Becauſe the retrograde motions of the ſuperior planets depend upon the motions of the earth; but thoſe of the inferior on their own angular motion. A ſuperior one is retrograde once in each revolution of the earth; an inferior one in every revolution of it's own.

The ſuperior planets are ſometimes nearer the earth than at other times; they alſo appear larger, or ſmaller, according to their different diſtances from us. Thus ſuppoſe the earth to be at C; if Mars

Mars be at P, he is the whole diameter of the earth's orbit nearer to us, than if he were at V, and confequently his difc muft appear larger at V than it would be at P. In other places, the diftances of Mars from the earth are intermediate.

The diameter of the earth's orbit bears a greater ratio to the diameter of the orbit of Mars, than it does to the diameter of the orbit of Jupiter; and a greater to that of Jupiter, than of Saturn; and confequently the difference between the greateft and leaft apparent diameters is greater in Mars than in Jupiter, and greater in Jupiter than in Saturn.

The fuperior, like the inferior planets, do not always appear in the ecliptic, their orbits being inclined alfo to that of the earth; one half is therefore above the ecliptic, the other half below it, nor are they ever feen in it but when they are in their nodes.

If, therefore, two planets happen to be in conjunction, at the time they come near the node of one of them, they would be feen from the fun apparently to touch one another; and the fartheft of thofe planets from the fun would fee the neareft moving over the face of the fun, like a black fpot, being then directly between the fun and the remoter planet. So the planet Venus was obferved from the earth, in the tranfits of the years 1761, and 1769. Alfo, fhould an oppo-

fition

ſition of two planets happen near a node of one of them, the ſun being then directly between them, would hide the light of one from the other.

That the Planets are opake Bodies, and derive their Light from the Sun.

That the planets are all opake, or dark bodies, and conſequently ſhine only by the light they receive from the ſun, is plain, becauſe they are not viſible when they are in ſuch parts of their orbits as are between the ſun and earth, that is, when their illuminated ſide is turned from us.

The ſun enlightens only half a planet at once; the illuminated hemiſphere is always that which is turned towards the ſun, the other hemiſphere of the planet is dark. To ſpeak with accuracy, the ſun being larger than any of the planets, will illuminate rather more than half; but this difference, on account of the great diſtance of the ſun from any of the planets, is ſo ſmall, that it's light may be conſidered as coming to them in lines phyſically parallel.

Like other opake bodies, they caſt a ſhadow behind them, which is always oppoſite to the ſun. The line in the planet's body, which diſtinguiſhes the lucid from the obſcure part, appears ſometimes ſtrait, ſometimes crooked. The convex part of the curve is ſometimes towards the ſplendid, and the concave towards that which is obſcure,

ſcure, and vice verſa, according to the ſituation of the eye with reſpect to the planet, and of the ſun which enlightens the planet.

Hence the inferior planets going round the ſun in leſs orbits than our earth does, will ſometimes have more, ſometimes leſs of their illuminated ſide towards us; and as it is the illuminated part only which is viſible to us, Mercury and Venus will, through a good teleſcope, exhibit the ſeveral appearances of the moon, from a fine thin creſcent to the enlightened hemiſphere.

If we view Venus through a teleſcope, when ſhe follows the ſun's rays on the eaſtern ſide, and appears above the horizon after ſun-ſet, we ſhall ſee her appear nearly round, and but ſmall; ſhe is at that time beyond the ſun, and preſents to us an enlightened hemiſphere. As ſhe departs from the ſun towards the eaſt, ſhe augments in her apparent ſize; and on viewing her through a teleſcope, is ſeen to alter her figure, abating of her apparent roundneſs, and appearing ſucceſſively like the moon, in the different ſtagesof her decreaſe. At length, when ſhe is at her greateſt elongation, ſhe is like the moon in her firſt quarter, and appears as ſhe does when from a full ſhe has decreaſed to half a moon.

After this, as ſhe approaches (in appearance) to the ſun, ſhe appears concave in her illuminated part, as the moon when ſhe forms a creſcent; thus ſhe continues till ſhe is hid entirely in the

ſun's rays, and preſents to us her whole dark hemiſphere, as the moon does in her conjunction, no part of the planet being then viſible.

When ſhe departs out of the ſun's rays on the weſtern ſide, we ſee her in the morning, juſt before day-break. It is in this ſituation that Venus is called the morning ſtar, as in the other ſhe is called the evening ſtar. She at this time appears very beautiful, like a fine thin creſcent: juſt a verge of ſilver light is ſeen on her edge. From this period ſhe grows more and more enlightened every day, till ſhe is arrived at her greateſt digreſſion or elongation, when ſhe again appears as a half moon, or as the moon in her firſt quarter; from this time, if continued to be viewed with a teleſcope, ſhe is found to be more and more enlightened, though ſhe is all the while decreaſing in magnitude, and thus continues growing ſmaller and rounder, till ſhe is again hid or loſt in the ſun's rays.

Fig. 1 and 2, plate IX. repreſents the orbits of Venus and the earth, with the ſun in the center of them. The planet Venus is drawn in eight different ſituations, with it's illuminated hemiſpheres towards the ſun. If we ſuppoſe the earth to be at T, when Venus is at A, her dark hemiſphere is towards the earth, and ſhe is therefore inviſible, except the conjunction happens in her node, for then ſhe appears like a dark ſpot upon

the difc of the fun. When Venus is at B, a little of her enlightened fide is turned towards the earth, and therefore fhe appears fharp-horned; when fhe is at C, half her enlightened hemifphere is turned towards the earth, and fhe appears like an half moon; at D, more than half her enlightened hemifphere is towards us, and fhe appears like the moon about three days before it is full; at E, the whole enlightened hemifphere is towards the earth, Venus is then either behind the fun, or fo very near him, that fhe can hardly be feen: but if fhe could, fhe would appear round, like the full moon. At F fhe is like the moon three days after the full; at G like a half moon again; at H like a crefcent, with the points of the horns turned the contrary way to what they were at B. All this is equally applicable to Mercury.

Fig. 2, plate IX. exhibits the different appearances of Venus, correfponding to her feveral fituations in the foregoing figure; thus when Venus is at A, fig. 1, fhe is quite dark, as at A, fig. 2; when fhe is at B, fig. 1, fhe appears as at B, fig. 2, &c.

The inferior planets do not fhine brighteft when they are full; thus Venus does not appear brighteft in her fuperior conjunction, though her illuminated hemifphere be then turned towards us. Her fplendor is more diminifhed by her being at a greater diftance from us, than the con-

fpicuous

ſpicuous part of her illuminated diſc is increaſed. Dr. Halley has ſhewn, that Venus is brighteſt when her elongation from the ſun is about 40°. Mercury is in his greateſt brightneſs, when very near his utmoſt elongation.

The ſuperior planets going round the ſun in larger orbits than the earth, always turn much the greater part of their enlightened hemiſphere towards it, and therefore appear round, like the full moon, except Mars, who ſometimes appears like the moon at a little diſtance from the full.

Jupiter and Saturn are ſo remote, that they turn very nearly the ſame hemiſphere towards us, that they do towards the ſun; for which reaſon, thoſe planets always appear round through the teleſcope.

Of the Moon's Motion.

It has been already obſerved, that four of the primary planets, the earth, Jupiter, Saturn, and the Georgium Sidus, are, in their revolutions round the ſun, attended by ſecondary planets.

As the moon turns round the earth, enlightening our nights, by reflecting the light ſhe receives from the ſun, ſo do the other ſatellites enlighten the planets to which they belong, and move round thoſe planets at different periods of time, proportioned to their ſeveral diſtances; and as the moon keeps company with this earth, in it's

annual

annual revolution round the ſun, ſo do they ſeverally accompany the planets to which they belong in their ſeveral courſes round that luminary.

We ſhall ſpeak here only of the moon, which of all the heavenly bodies, excepting the ſun, is the moſt ſplendid and brilliant, the inſeparable companion and attendant of our earth. In mythology ſhe was conſidered as Luna, in the heavens the radiant planet of the night, upon earth as the chaſte Diana, and as the tremendous Hecate in hell.

If we imagine the plane of the moon's orbit to be extended to the ſphere of the heaven, it would mark therein a great circle, which may be called the moon's apparent orbit; becauſe the moon appears to the inhabitants of the earth to move in that circle, through the twelve ſigns of the zodiac, in a periodical month. This poſition is illuſtrated by the following figure; let E F G H I, fig. 3, plate X. be the orbit of the earth, S the ſun, a b c d the orbit of the moon, when the earth is at E: let A B C D be a great circle in the ſphere of the heaven, in the ſame plane with the moon's orbit. The moon, by going round her orbit according to the order of letters, appears to an inhabitant of the earth to go round in the great circle A B C D, according to the order of thoſe letters: for when the moon is at a, ſeen from the earth at E, ſhe appears at A; when the moon is got to b, ſhe appears at B; when to c, ſhe will

appear

appear at C; when arrived at d, ſhe will appear at D. It is true, when the moon is at b, the viſual line drawn from E, through the moon, terminates in L; as it does in M, when the moon is at d; but the lines L M and D B being parallel, and not farther diſtant from each other than the diſtance of the earth's orbit, are as to ſenſe coincident, their diſtance meaſured in the ſphere of the heaven being inſenſible; for the ſame reaſon, though the earth moves from E to F, in the time that the moon goes round her orbit, ſo that at the end of a periodical month the moon will be at a, and is ſeen from the earth at F, in the line F N; the moon will, notwithſtanding, appear at A, the lines F N and E A being parallel, and as to ſenſe coincident: in like manner, in whatever part of her orbit the earth is, as at H or I, the moon, by going round in her orbit, will appear to an inhabitant of the earth to go round in the great circle A B C D.

The plane of the moon's orbit extended to the heavens, cuts the ecliptic in two oppoſite points.

The two points where the moon's apparent orbit thus cuts the ecliptic, are called the MOON'S NODES.

The point where the moon appears to croſs the ecliptic, as ſhe goes into north latitude, is called the moon's aſcending node, of which this is the character ☊; the point where the moon goes

goes into ſouth latitude is her deſcending node, and is marked thus ☋; the moon's aſcending node is often called the dragon's head; her deſcending node is called the dragon's tail.

The LINE OF THE MOON'S NODE is a line drawn from one node to the other.

The extremities of the line of the nodes are not always directed towards the ſame points of the ecliptic, but continually ſhift their places from eaſt to weſt, or contrary to the order of the ſigns, performing an entire revolution about the earth, in the ſpace of ſomething leſs than nineteen years.

The moon appears in the ecliptic only when ſhe is in one of her nodes; in all other parts of her orbit ſhe is either in north or ſouth latitude, ſometimes nearer to, ſometimes further removed from the ecliptic, according as ſhe happens to be more or leſs diſtant from the nodes.

When the place in which the moon appears to an inhabitant of the earth, is the ſame with the ſun's place, ſhe is ſaid to be in CONJUNCTION. When the moon's place is oppoſite to the ſun's place, ſhe is ſaid to be in OPPOSITION. When ſhe is a quarter of a circle diſtant from the ſun, ſhe is ſaid to be in QUADRATURE. Both the conjunction and oppoſition of the moon are termed SYZIGIES.

The common lunar month, or the time that paſſes between any new moon and the next that

follows it, is called A SYNODICAL MONTH, or A LUNATION. This month contains 29 days, 12 hours, 44 minutes, 3 ſeconds.

A PERIODIC MONTH is the time the moon takes up to deſcribe her orbit; or in other words, the time in which the moon performs one entire revolution about the earth, from any point in the zodiac to the ſame again ; and contains 27 days, 7 hours, 43 minutes.

If the earth had no revolution round the ſun, or the ſun no apparent motion in the ecliptic, the periodical and ſynodical month would be the ſame; but as this is not the caſe, the moon takes up a longer time to paſs from one conjunction to the next, than to deſcribe it's whole orbit; or the time between one new moon and the next, is longer than the moon's periodical time.

The moon revolves round the earth from weſt to eaſt, and the ſun apparently revolves round the earth the ſame way. Now at the new moon, or when the ſun and moon are in conjunction, they both ſet out from the ſame place, to move the ſame way round the earth ; but the moon moves much faſter than the ſun, and conſequently will overtake it; and when the moon does overtake it, it will be a new moon again. If the ſun had no apparent motion in the ecliptic, the moon would come up to it, or be in conjunction again, after it had gone once round in

it's orbit; but as the ſun moves forward in the ecliptic, whilſt the moon is going round, the moon muſt move a little more than once round, before it comes even with the ſun, or before it comes to conjunction. Hence it is that the time between one conjunction, and the next in ſucceſſion, is ſomething more than the time the moon takes up to go once round it's orbit; or a ſynodical month is longer than a periodical one.

In fig. 3, plate IX. let S be the ſun, C F a part of the earth's orbit, M D a diameter of the moon's orbit when the earth is at A, and m d another diameter parallel to the former, when the earth is at B. Whilſt the earth is at A, if the moon be at D, ſhe will be in conjunction; and if he earth was to continue at A, when the moon had gone once round it's orbit, from D through M, ſo as to return to D again, it would again be in conjunction. Therefore, upon the ſuppoſition that the earth has no motion in it's orbit, the periodical and ſynodical months would be equal to one another. But as the earth does not continue at A, it will move forwards in it's orbit, during the revolution of the moon from A to B; and as the moon's orbit moves with it, the diameter M D will then be in the poſition m d; therefore, when the moon has deſcribed it's orbit, it will be at d in this diameter m d; but if the moon is at d, and the ſun at S, the moon will not be in

conjunction, consequently the periodical month is completed before the synodical. The moon, in order to come to conjunction, when the earth is at B, must be at e, in the diameter e f; or besides going once round in it's orbit, it must also describe the arc d e. The synodical month is, therefore, longer than the periodical, by the time the moon takes up to describe the arc d e.

This may be also explained in another manner, by considering the motion of the sun; a view of the subject, that may render it more easy to some young minds than the foregoing. Thus let us suppose the earth at rest at E, fig. 4, plate IX. M the moon in conjunction with the sun at S, while the moon describes her orbit A B C about the earth at E, let the sun advance by his apparent annual motion from S to D. It is plain that the moon will not come in conjunction with the sun again, till, besides describing her orbit, she hath described, over and above, the arch M F, corresponding to the arch S D.

As the moon goes round the earth in a much smaller orbit than that in which the earth revolves round the sun, sometimes more, sometimes less, and sometimes no part of her enlightened half will be towards us; hence she is incessantly varying her appearance; sometimes she looks full upon us, and her visage is all lustre, sometimes she shews only half her enlightened face, soon she appears as a radiant crescent, in a little

a little time all her brightneſs vaniſhes and ſhe becomes a beamleſs orb.

The full moon, or oppoſition, is that ſtate in which her whole diſk is enlightened, and we ſee it all bright, and of a circular figure. The new moon is when ſhe is in conjunction with the ſun; in this ſtate, the whole ſurface turned towards us is dark, and ſhe is therefore inviſible to us.

The firſt quarter of the moon ſhe appears in the form of a ſemicircle, whoſe circumference is turned towards the weſt. At the laſt quarter, ſhe appears again under the form of a ſemicircle, but with the circumference turned towards the eaſt.

Theſe phaſes may be illuſtrated in a very pleaſing manner to the pupil, by expoſing an ivory ball to the ſun, in a variety of poſitions, by which it may preſent a greater or ſmaller part of it's illuminated ſurface to the obſerver. If it be held nearly in oppoſition, ſo that the eye of the obſerver may be almoſt immediately between it and the ſun, the greateſt part of the enlightened ſide will be ſeen; but if it be moved in a circular orbit, towards the ſun, the viſible enlightened part will gradually decreaſe, and at laſt diſappear, when the ball is held directly towards the ſun. Or to apply the experiment more immediately to our purpoſe; if the ball, at any time when the ſun and moon are both viſible, be held directly between the eye of the obſerver and the moon,

that part of the ball on which the ſun ſhines, will appear exactly of the ſame figure as the moon itſelf.

The phaſes of the moon, like thoſe of Venus, may alſo be illuſtrated by a diagram; thus in fig. 1, plate X. let S be the ſun, T the earth, A B C D E F G H the orbit of the moon. The firſt obſervation to be deduced from this figure, is that the half of the earth and moon which is towards the ſun, is wholly enlightened by it; and the other half, which is turned from it, is totally dark. When the moon is in conjunction with the ſun at A, her enlightened hemiſphere is turned towards the ſun, and the dark one towards the earth; in which caſe, we cannot ſee her, and it is ſaid to be new moon. When the moon has moved from A to B, a ſmall portion a b of her enlightened hemiſphere will be turned towards the earth; which portion will appear of the form repreſented at B, fig. 2, plate XI. (a figure which exhibits the phaſes as they appear to us).

As the moon proceeds in her orbit, according to the order of the letters, more and more of her enlightened part is turned towards the earth. When ſhe arrives at C, in which poſition ſhe is ſaid to be in quadrature, one half of that part towards the earth is enlightened, appearing as at C among the phaſes; this appearance is called a half moon. When ſhe comes to D, the greateſt

part

part of that half which is towards us is enlightened; the moon is then ſaid to be gibbous, and of that figure which is ſeen at D, in fig. 2.

When the moon comes to F, ſhe is in oppoſition to the ſun, and conſequently turns all her illuminated ſurface towards the earth, and ſhines with a full face, for which reaſon ſhe is called a full moon. As ſhe paſſes through the other half of her orbit, from E by F G, and H to A again, ſhe puts on the ſame faces as before, but in a contrary order or poſition.

As the moon, by reflected light from the ſun, illuminates the earth, ſo the earth does more than repay her kindneſs, in enlightening the ſurface of the moon, by the ſun's reflex light, which ſhe diffuſes more abundantly upon the moon, than the moon does upon us; for the ſurface of the earth is conſiderably greater than that of the moon, and conſequently if both bodies reflect light in proportion to their ſize, the earth will reflect much more light upon the moon, than it receives from it.

In new moon, the illuminated ſide of the earth is fully turned towards the moon, and the Lunarians will have a full earth, as we, in a ſimilar poſition, have a full moon. And from thence ariſes that dim light which is obſerved in the old and new moons, whereby, beſides the bright and ſhining horns, we can perceive the reſt of her

body behind them, though but dark and obſcure. Now when the moon comes to be in oppoſition to the ſun, the earth, ſeen from the moon, will appear in conjunction with him, and it's dark ſide will be turned towards the moon, in which poſition the earth will be inviſible to the Lunarians; after this, the earth will appear to them as a creſcent. In a word, the earth exhibits the ſame appearance to the inhabitants of the moon, that the moon does to us.

The moon turns about it's own axis in the ſame time that it moves round the earth; it is on this account that ſhe always preſents nearly the ſame face to us: for by this motion round her axis, ſhe turns juſt ſo much of her ſurface conſtantly towards us, as by her motion about the earth would be turned from us. This motion about her axis is equable and uniform, but that about the earth is unequal and irregular, as being performed in an ellipſis; conſequently the ſame preciſe part of the moon's ſurface can never be ſhewn conſtantly to the earth; which is confirmed by a teleſcope, by which we often obſerve a little ſegment on the eaſtern and weſtern limb, appear and diſappear by turns, as if her body librated to and fro; this phænomenon is called the moon's LIBRATION. The lunar motions are ſubject to ſeveral other irregularities, which are fully diſcuſſed in the larger works on aſtronomy.

OF ECLIPSES.

Thoſe phænomena that are termed eclipſes, were in former ages beheld with terror and amazement, and looked upon as prodigies that portended calamity and miſery to mankind. Theſe fears, and the erroneous opinions which produced them, had their ſource in the hieroglyphical language of the firſt inhabitants of the earth. We do not, however, imagine that even the moſt ancient of theſe knew any more of the laws and motions of the heavenly bodies, than what could be diſcovered from immediate ſight; or that they knew enough of the lunar ſyſtem to calculate an eclipſe, or even that they ever attempted it.

The word ECLIPSE is derived from the Greek, and ſignifies dereliction, a fainting away, or ſwooning. Now as the moon falls into the ſhadow of the earth, and is deprived of the ſun's enlivening rays, at the time of her greateſt brightneſs, and even appears pale and languid before her obſcuration, lunar eclipſes were called LUNÆ LABORES, the ſtruggles or labours of the moon; to relieve her from theſe imagined diſtreſſes, ſuperſtition adopted methods as impotent as they were abſurd.

When the moon, by paſſing between us and the ſun, deprived the earth of it's light and heat, the ſun was thought to turn away his face, as if in abhor-

abhorrence of the crimes of mankind, and to threaten everlafting night and deftruction to the world. But thanks to the advancement of fcience, which, while it has delivered us from the foolifh fears and idle apprehenfions of the ancients, leaves us in poffeffion of their reprefentative knowledge, enables us to explain the appearances on which it was founded, and points out the perverfion and abufe of it.

Any opake body that is expofed to the light of the fun, will caft a fhadow behind it. This fhadow is a fpace deprived of light, into which if another body comes, it cannot be feen for want of light; the body thus falling within the fhadow, is faid to be ECLIPSED.

The earth and moon being opake bodies, and deriving their light from the fun, do each of them caft a fhadow behind, or towards the hemifphere oppofed to the fun. Now when either the moon or the earth paffes through the other fhadow, it is thereby deprived of illumination from the fun, and becomes invifible to a fpectator on the body from whence the fhadow comes; and fuch fpectator will obferve an eclipfe of the body which is paffing through the fhadow; while a fpectator on the body which paffes through the fhadow, will obferve an eclipfe of the fun, being deprived of his light.

Hence there muft be three bodies concerned in an eclipfe; 1. the luminous body; 2. the opake body,

body, that casts the shadow; and, 3. the body involved in the shadow.

Of Eclipses of the Moon.

As the earth is an opake body, enlightened by the sun, it will cast a shadow towards those parts that are opposite to the sun, and the axis of this shadow will always be in the plane of the ecliptic, because both the sun and the earth are always there.

The sun and the earth are both spherical bodies; if they were, therefore, of an equal size, the shadow of the earth would be cylindrical, as in fig. 5, plate IX. and would continue of the same breadth at all distances from the earth, and would consequently extend to an infinite distance, so that Mars, Jupiter, or Saturn, might be eclipsed by it; but as these planets are never eclipsed by the earth, this is not the shape of the shadow, and consequently the earth is not equal in size to the sun.

If the sun were less than the earth, the shadow would be wider, the farther it was from the earth, see fig. 6, plate IX. and would therefore reach to the orbits of Jupiter and Saturn, and eclipse any of these planets when the earth came between the sun and them; but the earth never eclipses them, therefore this is not the shape of it's shadow, and consequently the sun is not less than the earth.

As we have proved that the earth is neither larger nor equal to the ſun, we may fairly conclude that it is leſs; and that the ſhadow of the earth is a cone, which ends in a point at ſome diſtance from the earth, ſee fig. 7, plate IX.

The axis of the earth's ſhadow falls always upon that point of the ecliptic that is oppoſite to the ſun's geocentric place; thus if the ſun be in the firſt point of Aries, the axis of the earth's ſhadow will terminate in the firſt point of Libra. It is clear, therefore, that there can be no eclipſe of the moon but when the earth is interpoſed between it and the ſun, that is, at the time of it's oppoſition, or when it be full; for unleſs it is oppoſite to the ſun, it can never be in the earth's ſhadow: and if the moon did always move in the plane of the ecliptic, ſhe would every full moon paſs through the body of the ſhadow, and there would be a total eclipſe of the moon.

We have already obſerved, that the moon's orbit is inclined to the plane of the ecliptic, and only coincides with it in two places, which are termed the nodes. It may, therefore, be full moon * without her being in the plane of the ecliptic;

* A planet may be in oppoſition to, or conjunction with the ſun, without being in a right line that paſſes through the ſun and the earth. Aſtronomers term it in conjunction with the ſun, if it be in the ſame part of the zodiac; in oppoſition, if it be in a part of the zodiac, 180° from the ſun.

ecliptic; ſhe may be either on the north or the ſouth ſide of it; in either of theſe caſes, ſhe will not enter into the ſhadow, but be above it in the one, below it in the other.

To illuſtrate this, let H G, fig. I, plate XI. repreſent the orbit of the moon, E F the plane of the ecliptic, in which the center of the earth's ſhadow always moves, and N the node of the moon's orbit; A B C D four places of the ſhadow of the earth in the ecliptic. When the ſhadow is at A, and the moon at I, there will be no eclipſe; when the full moon is nearer the node, as at K, only part of her globe paſſes through the ſhadow, and that part becoming dark, it is called a PARTIAL ECLIPSE; and it is ſaid to be of ſo many DIGITS as there are TWELFTH PARTS of the moon's diameter darkened. When the full moon is at M, ſhe enters into the ſhadow C, and paſſing through it becomes wholly darkened at L, and leaves the ſhadow at O; as the whole body of the moon is here immerſed in the ſhade, this is called a TOTAL ECLIPSE. But when the moon's center paſſes through that of the ſhadow, which can only happen when ſhe is in the node at N, it is called a TOTAL AND CENTRAL ECLIPSE. There will always be ſuch eclipſes, when the center of the moon, and axis of the ſhadow, meet in the nodes.

The

The duration of a central eclipſe is ſo long, as to let the moon go the length of three of it's diameters totally eclipſed, which ſtay in the earth's ſhadow is computed to be about four hours; whereof the moon takes one hour from it's beginning to enter the ſhadow, till quite immerſed therein; two hours more ſhe continues totally dark; and the fourth hour is taken up from her firſt beginning to come out of the ſhadow, till ſhe is quite out of it.

In the beginning of an eclipſe, the moon enters the weſtern part of the ſhadow with the eaſtern part of her limb, and, in the end of it ſhe leaves the eaſtern part of the ſhadow with the weſtern part of her limb; all the intermediate time, from her entrance to her quitting the ſhadow, is reckoned into the eclipſe; but only ſo much into the total immerſion, as paſſes while the moon is altogether obſcured.

From the magnitude of the ſun, the ſize of the earth, their diſtance from each other, the refraction of the atmoſphere, and the diſtance of the moon from the earth; it has been calculated that the ſhadow of the earth terminates in a point, which does not reach ſo far as the moon's orbit. The moon is not, therefore, eclipſed by the ſhadow of the earth alone. The atmoſphere, by refracting ſome of the rays of the ſun, and reflecting others, caſts a ſhadow, though not ſo dark a one as that which ariſes from an opake body;

body; when, therefore, we ſay that the moon is eclipſed, by paſſing into the ſhadow of the earth, it is to be underſtood of the ſhadow of the earth, together with it's atmoſphere. Hence it is that the moon is viſible in eclipſes, the ſhadow caſt by the atmoſphere not being ſo dark as that caſt by the earth. The cone of this ſhadow is larger than the cone of the earth's ſhadow, the baſe thereof broader, the axis longer. There have been eclipſes of the moon in which the moon has entirely diſappeared: Hevelius mentions one of this kind, which happened in Auguſt 1647, when he was not able to diſtinguiſh the place of the moon, even with a good teleſcope, although the ſky was ſufficiently clear for him to ſee the ſtars of the fifth magnitude.

All opake bodies, when illuminated by the rays of the ſun, caſt a ſhadow from them, which is encompaſſed by a PENUMBRA, or thinner ſhadow, which every where ſurrounds the former, growing larger and larger as we recede from the body: in other words, the penumbra is all that ſpace ſurrounding the ſhadow, into which the rays of light can only come from ſome part of that half of the globe of the ſun, which is turned towards the planet, all the reſt being intercepted by the intervening body.

Let S, fig. 2, plate XI. be the ſun, E the planet, then the penumbral cone is F G H. The

The nearer any part of the penumbra is to the ſhadow, the leſs light it receives from the ſun; but the further it is, the more it is enlightened; thus the parts of the penumbra near M are illuminated by thoſe rays of light, which come from that part of the ſun near to I, all the reſt being intercepted by the planet E; in like manner, the parts about N can only receive the light that comes from the part of the ſun near to L, whereas the parts of the penumbra at P and Q are enlightened in a much greater degree: for the planet intercepts from P only thoſe rays which come from the ſun near L, and hides from Q only a ſmall part of the ſun near I.

The moon paſſes through the penumbra before ſhe enters into the ſhadow of the atmoſphere; this cauſes her gradually to loſe her light, which is not ſenſible at firſt, but as ſhe goes into the darker part of the penumbra, ſhe grows paler; the penumbra, where it is contiguous to the ſhadow, is ſo dark, that it is difficult to diſtinguiſh one from the other. If the atmoſphere be ſerene, every eclipſe of the moon is viſible at the ſame inſtant to all the inhabitants of that ſide of the earth to which ſhe is oppoſite.

The moon, in a total eclipſe, generally appears of a duſky reddiſh colour, eſpecially towards the edges; but of a darker towards the middle of the ſhadow.

Of

Of Eclipses of the Sun.

The moon, when in conjunction, if near one of her nodes, will be interpofed between us and the fun, and will confequently hide the fun, or a part of him, from us, and caft a fhadow upon the earth : this is called an ECLIPSE OF THE SUN ; it may be either partial or total.

An eclipfe of any lucid body, is a deficiency or diminution of light, which would otherwife come from it to our eye, and is caufed by the interpofition of fome opake body.

The eclipfes of the fun and moon, though expreffed by the fame word, are in nature very different; the fun, in reality, lofes nothing of it's native luftre in the greateft eclipfes, but is all the while inceffantly fending forth ftreams of light every way round him, as copioufly as before. Some of thefe ftreams are, however, intercepted in their way towards our earth, by the moon coming between the earth and the fun : and the moon having no light of her own, and receiving none from the fun on that half of the globe which is towards our eye, muft appear dark, and make fo much of the fun's difk appear fo, as is hid from us by her interpofition.

What is called an eclipfe of the fun, is therefore, in reality, an eclipfe of the earth, which is

deprived of the ſun's light, by the moon's coming between, and caſting a ſhadow upon it. The earth being a globe, only that half of it which at any time is turned towards the ſun, can be enlightened by him at that time; it is upon ſome part of this enlightened half of the earth, that the moon's ſhadow, or penumbra, falls in a ſolar eclipſe.

The ſun is always in the plane of the ecliptic; but the moon being inclined to this plane, and only coinciding with it at the nodes, it will not cover either the whole or a part of the ſun; or in other words, the ſun will not be eclipſed, unleſs the moon at that time is in or near one of her nodes.

The moon, however, cannot be directly between the ſun and us, unleſs they are both in the ſame part of the heavens; that is, unleſs they are in conjunction. Therefore, the ſun can never be eclipſed but at the new moon, nor even then, unleſs the moon at that time is in or near one of her nodes.

From hence it is eaſy to ſhew, that the darkneſs of our Saviour's crucifixion was not owing to an eclipſe of the ſun. For the crucifixion happened at the time of the Jewiſh paſſover, and the paſſover, by the appointment of the law, was to be celebrated at the full moon; the ſun could not, therefore, be eclipſed at the time of the paſſover. An intelligent tutor will find many opportunities

of

of obſerving to his pupil, that nature, and philoſophy, which explains the phænomena of nature, do always agree with divine revelation.

The moon being much ſmaller than the earth, and having a conical ſhadow, becauſe ſhe is leſs than the ſun, can only cover a ſmall part of the earth by her ſhadow; though, as we have obſerved before, the whole body of the moon may be involved in that of the earth. Hence an eclipſe of the ſun is viſible but to a few inhabitants of the earth; whereas, an eclipſe of the moon may be ſeen by all thoſe that are on that hemiſphere which is turned towards it. In other words, as the moon can never totally eclipſe the earth, there will be many parts of the globe that will ſuffer no eclipſe, though the ſun be above their horizon.

An eclipſe of the ſun always begins on the weſtern, and ends on the eaſtern ſide; becauſe the moon moving in her orbit from weſt to eaſt, neceſſarily firſt arrives at and touches the ſun's weſtern limb, and goes off at the eaſtern.

It is not neceſſary, in order to conſtitute a CENTRAL eclipſe of the ſun, that the moon ſhould be exactly in the line of the nodes, at the time of it's conjunction; for it is ſufficient to denominate an eclipſe of the ſun CENTRAL, that the center of the moon be directly between the center of the ſun, and the eye of the ſpectator; for to him, the ſun is then centrally eclipſed. But as the

ſhadow of the moon can cover but a ſmall portion of the earth, it is obvious this may happen when the moon is not in one of her nodes. Further, the ſun may be eclipſed centrally, totally, partially, and not at all at the ſame time.

A total eclipſe of the ſun is a very curious ſpectacle: Clavius ſays that, in that which he obſerved in Portugal, in 1650, the obſcurity was greater, or more ſenſible than that of the night: the largeſt ſtars made their appearance for about a minute or two, and the birds were ſo terrified, that they fell to the ground.

Thus in fig. 3, plate XI. let A B C be the ſun, M N the moon, h l g part of the cone of the moon's ſhadow, f d the penumbra of the moon: from this figure it is eaſy to perceive,

1. That thoſe parts of the earth that are within the circle repreſented by g h, are covered by the ſhadow of the moon, ſo that no rays can come from any part of the ſun into that circle, on account of the interpoſition of the moon.

2. In thoſe parts of the earth where the penumbra falls, only part of the ſun is viſible; thus between d and g, the parts of the ſun near C cannot be ſeen, the rays coming from thence towards d or g being intercepted by the moon; whereas at the ſame time, the parts between f and h are illuminated by rays coming from C, but are deprived by the moon of ſuch as come from A.

3. The nearer any part of the earth, within the

the penumbra, is to the ſhadow of the moon, as in places near g, l, or h, the leſs portion of the ſun is viſible to it's inhabitants; the nearer it is to the outſide of the penumbra, as towards d, e, or f, the greater portion of the ſun may be ſeen.

4. Out of the penumbra, the entire diſk of the ſun is viſible.

Of the Limits of Solar and Lunar Eclipses.

The diſtance of the moon in degrees and minutes, above or below the ecliptic line, is called her LATITUDE. If ſhe be above the ecliptic, ſhe is ſaid to have north; if below it, ſouth latitude.

If the latitude at any time exceed the ſum of the ſemi-diameter of the moon, equal to 16¼ minutes, and the earth's ſhadow equal to 45¾ minutes, the moon at that time cannot be eclipſed; but will either paſs under or over the ſhadow, according as ſhe happens to be above or below the ecliptic line.

The diſtance from the node, either before or after it, correſponding to the above extent, is about 12 degrees, which is conſequently the limit of lunar eclipſes. For when a full moon happens within 12 degrees of the nodes, ſhe will be eclipſed; and the nearer to the nodes, the greater will the eclipſe be.

If at the new moon, the latitude of the moon exceeds the ſum of the ſemi-diameters of the ſun 16¼ min. and of the moon 16¾ min. we ſhould

ſee no eclipſe of the ſun from the center of the earth. But as we view the luminaries from the ſurface, which is much higher, we are obliged to take in the ſemi-diameter of the earth as ſeen from the moon. Then, if the latitude of the moon be greater than the ſum of theſe 3 numbers, 94¾ minutes, the ſun will not be eclipſed; for the moon will paſs either over or under his diſk, according as ſhe is above or below the ecliptic line. The diſtance from the node on either ſide agreeing to the above-mentioned extent, is the 18 degrees, which is the utmoſt limit of ſolar eclipſes. Whence it follows, that if the ſun and moon, at the time of new moon, happen to be within 18 deg. of the node, the ſun will be eclipſed.

Of the Period of Eclipses.

If the places of the moon's nodes were fixed, eclipſes would always happen nearly at the ſame time of the year: but as they have a motion of about 3 min. 11 ſec. every day backwards, or contrary to the order of the ſigns, the ſucceeding eclipſe muſt recede likewiſe; and in one revolution of the nodes, which is completed in 18 years, 224 days, 3 hours, they will revolve in a retrograde manner through the year, and return to the ſame places again.

But there is a more correct period, called the Chaldean Saros, which is 18 years, 11 days,

7 hours, 43 min. For in that time the ſun and moon advance juſt as far beyond a complete direct revolution in the ecliptic, as the nodes want of completing their retrograde one: conſequently, as the ſun and moon meet the nodes at the end of that period, the ſame ſolar and lunar aſpects which happened 18 years, 11 days, 7 hours, 43 min. ago, will return, and produce eclipſes of both luminaries, for many ages, the ſame as before.

Of ancient aſtronomical obſervations much has been ſaid, with very little foundation, by many modern writers: the oldeſt eclipſes of the moon that Hipparchus could make any uſe of, went no higher than the year before Chriſt 721. Whatever obſervations therefore the Chaldeans had before this, were probably very rude and imperfect.*

Of Parallax and Refraction.

Aſtronomy is ſubject to many difficulties, beſides thoſe which are obvious to every eye. When we look at any ſtar in the heavens, we do not ſee it in it's real place; the rays coming from it, when they paſs out of the purer etherial medium, into our coarſer and more denſe atmoſphere, are REFRACTED, or bent in ſuch a manner, as to ſhew the ſtar higher than it really is.

* Coſtard's Hiſtory of Aſtronomy.

Hence we ſee all the ſtars before they riſe, and after they ſet; and never, perhaps, ſee any one in it's true place in the heavens. There is another difference in the apparent ſituation of the heavenly bodies, which ariſes from the ſtations in which an obſerver views them. This difference in ſituation is called the PARALLAX of an object.

Of Parallax.

The PARALLAX of any object is the difference between the places that the object is referred to in the celeſtial ſphere, when ſeen at the ſame time from two different places within that ſphere. Or, it is the angle under which any two places in the inferior orbits are ſeen from a ſuperior planet, or even the fixed ſtars.

The parallaxes principally uſed by aſtronomers, are thoſe which ariſe from conſidering the object as viewed from the centers of the earth and the ſun, from the ſurface and center of the earth, and from all three compounded.

The difference between the place of a planet, as ſeen from the ſun, and the ſame as ſeen from the earth, is called the parallax of the annual orbit; in other words, the angle at any planet, ſubtended between the ſun and the earth, is called the parallax of the earth's or annual orbit.

The diurnal parallax is the change of the apparent place of a fixed ſtar, or planet, of any

celeſtial

celeſtial body, ariſing from it's being viewed on the ſurface, or from the center of the earth.

The annual parallax of all the planets, is very conſiderable, but that of the fixed ſtars is imperceptible.

The fixed ſtars have no diurnal parallax, the moon a conſiderable one; that of the planets is greater or leſs, according to their diſtances.

To explain the parallaxes with reſpect to the earth only, let H S W, fig. 2, plate VIII. repreſent the earth, T the center thereof, o R G part of the moon's orbit, P r g part of a planet's orbit, Z a A part of the ſtarry heavens. Now to a ſpectator at S, upon the ſurface of the earth, let the moon appear in G, that is, in the ſenſible horizon of S, and it will be referred to A; but if viewed from the center T, it will be referred to the point D, which is it's true place.

The arc A D will be the moon's parallax; the angle S G T the parallactic angle; or the parallax is expreſſed by the angle under which the ſemidiameter T S of the earth is ſeen from the moon.

If the parallax be conſidered with reſpect to different planets, it will be greater or leſs, as thoſe objects are more or leſs diſtant from the earth; thus the parallax A D of G is greater than the parallax a d of g.

If it be conſidered with reſpect to the ſame planet, it is evident that the horizontal parallax (or

(or the parallax when the object is in the horizon) is greateſt of all, and diminiſhes gradually, as the body riſes above the horizon, until it comes to the zenith, where the parallax vaniſhes, or becomes equal to nothing. Thus A D and a d, the horizontal parallaxes of G and g, are greater than a B and a b, the parallaxes of R and r; but the objects O and P, ſeen from S or T, appear in the ſame place Z, or the zenith.

By knowing the parallax of any celeſtial object, it's diſtance from the center of the earth may be eaſily obtained by trigonometry. Thus if the diſtance of G from T be ſought, in the triangle S T G, S T being known, and the angle S G T determined by obſervation, the ſide T G is thence known.

The parallax of the moon may be determined by two perſons obſerving her from different ſtations at the ſame time, ſhe being vertical to the one, and horizontal to the other. It is generally concluded to be about 57′ of a °.

But the parallax moſt wanted, is that of the ſun, whereby his abſolute diſtance from the earth would be known; and hence the abſolute diſtances of all the other planets would be alſo known, from the ſecond Keplerian law. But the parallax of the ſun, or the angle under which the ſemidiameter of the earth would appear at that diſtance, is ſo exceeding ſmall, that a miſtake of a

ſecond

ſecond will cauſe an error of ſeveral millions of miles.

Of Refraction.

As one of the principal objects of aſtronomy is to fix the ſituation of the ſeveral heavenly bodies, it is neceſſary, as a firſt ſtep, to underſtand the cauſes which occaſion a falſe appearance of the place of thoſe objects, and make us ſuppoſe them in a different ſituation from that which they really have. Among theſe cauſes, REFRACTION is to be reckoned. By this term is meant, the bending of the rays of light as they paſs out of one medium into another.

The earth is every where ſurrounded by an heterogeneous fluid, a mixture of air, vapour, and terreſtrial exhalations, that extend to the regions of the ſky. The rays of light from the ſun, moon, and ſtars, in paſſing to a ſpectator upon earth, come through this medium, and are ſo refracted in their paſſage through it, that their apparent altitude is greater than their true altitude.

Let A C, fig. 3, plate VIII. repreſent the ſurface of the earth, T it's center, B P a part of the atmoſphere, H E K the ſphere of the fixed ſtars, A F the ſenſible horizon, G a planet, G D a ray of light proceeding from the planet to D, where it enters our atmoſphere, and is refracted towards the line D T, which is perpendicular to the ſurface

face of the atmoſphere; and as the upper air is rarer than that near the earth, the ray is continually entering a denſer medium, and is every moment bent towards T, which cauſes it to deſcribe a curve as D A, and to enter a ſpectator's eye at A, as if it came from E, a point above G. And as an object always appears in that line in which it enters the eye, the planet will appear at E, higher than it's true place, and frequently above the horizon A F, when it's true place is below it at G.

This refraction is greateſt at the horizon, and decreaſes very faſt as the altitude increaſes, inſomuch that the refraction at the horizon differs from the refraction at a very few degrees above the horizon, by about one-third part of the whole quantity. At the horizon, in this climate, it is found to be about 33′. In climates nearer to the equator, where the air is purer, the refraction is leſs; and in the colder climates, nearer to the pole, it increaſes exceedingly, and is a happy proviſion for lengthening the appearance of the light at thoſe regions ſo remote from the ſun. Gaſſendus relates, that ſome Hollanders who wintered in Nova Zembla, in latitude 75°, were ſurprized with a ſight of the ſun 17 days before they expected him in the horizon. This difference was owing to the refraction of the atmoſphere in that latitude. To the ſame cauſe, together with the peculiar obliquity

obliquity of the moon's orbit to the ecliptic, ſome of theſe very northern regions are indebted for an uninterrupted light from the moon much more than half the month, and ſometimes almoſt as long as it is capable of affording any light to other parts of the earth.

Through this refraction we are favoured with the ſight of the ſun, about 3 minutes and $\frac{1}{4}$ before it riſes above the horizon; and alſo as much every evening after it ſets below it, which in one year amounts to more than 40 hours.

It is to this property of refraction that we are alſo indebted for that enjoyment of light from the ſun when he is below the horizon, which produces the morning and evening twilight. The ſun's rays, in falling upon the higher part of the atmoſphere, are reflected back to our eyes, and form a faint light, which gradually augments till it becomes day. It is owing to this, that the ſun illuminates the whole hemiſphere at once; deprived of the atmoſphere, he would have yielded no light, but when our eyes were directed towards him; and even when he was in meridian ſplendor, the heavens would have appeared dark, and as full of ſtars as on a fine winter's night. The rays of light would have come to us in ſtrait lines, and the appearance and diſappearance of the ſun would have been inſtantaneous; we ſhould have had a ſudden tranſition from the brighteſt ſun-ſhine, to the moſt profound dark-

nefs, and from thick darknefs to a blaze of light. Thus by refraction we are prepared gradually for the light of the fun, the duration of it's light is prolonged, and the fhades of darknefs foftened.

To it we muft attribute another curious phænomenon, mentioned by Pliny: for he relates, that the moon had been eclipfed once in the weft, at the fame time that the fun appeared above the horizon in the eaft. Mæftlinus, in Kepler, fpeaks of another inftance of the fame kind, which fell under his own obfervation.

OF THE SATELLITES OF JUPITER AND SATURN.

The exiftence of the fatellites of any of the planets, except the moon, would have been unknown to us without the ufe of the telefcope. The fatellites are diftinguifhed according to their places, into firft, fecond, &c. the firft being that which is neareft to the planet. From all the obfervations that have been made on the fecondary planets, it appears, 1. That the fatellites revolve round their primaries in elliptic orbits, the primary planet being in the focus. 2. That the planes of the orbits of the fatellites are inclined to the planes of the orbits of their refpective planets. 3. That, like the primary planets, the fquares of the times of their revolutions,

tions, are as the cubes of the mean diſtances from their primary planet.

The following table ſhews the time taken by each ſatellite in it's revolution; and alſo it's mean diſtance from the primary planet in ſemi-diameters thereof.

Jupiter's Satellites.

I.	II.	III.	IV.
d. h. m.	*d. h. m.*	*d. h. m.*	*d. h. m.*
1 18 28	3 13 18	7 3 59	16 18 5

Distance from Jupiter in Semi-diameters.

I.	II.	III.	IV.
$5\frac{2}{3}$	9	$14\frac{1}{3}$	$25\frac{1}{3}$

Saturn's Satellites.

I.	II.	III.	IV.	V.
d. h. m.	*d. h. m.*	*d. h. m.*	*d. h. m.*	*d. h. m.*
1 21 18	2 17 41	3 12 25	15 22 41	79 7 48

Distance from Saturn in Semi-diameters.

I.	II.	III.	IV.	V.
$8\frac{7}{8}$	$11\frac{1}{4}$	15	36	108

The

The ſyſtem of Jupiter and his ſatellites is very large in itſelf; yet on account of it's immenſe diſtance from us, it appears to occupy but a ſmall ſpace in the ſphere of the ſtarry heavens, and conſequently every ſatellite of Jupiter appears to us always near it's primary, and to have an oſcillatory motion, like that of a pendulum going alternately from it's greateſt digreſſion on one ſide the planet, to it's greateſt on the other, ſometimes in a ſtrait line, at others in an elliptic curve.

When a ſatellite is in it's ſuperior ſemicircle, or that half of it's orbit that is more diſtant from the earth than Jupiter, it's motion appears direct to us; when a ſatellite is in it's inferior ſemicircle, nearer to us than Jupiter is, the apparent motion of it is retrograde. Both theſe motions ſeem quickeſt, when the ſatellite is neareſt the center of the primary, and ſlower when they are more diſtant; at the greateſt diſtance they appear ſtationary for a ſhort time.

The ſatellites of Saturn revolve about it in almoſt the ſame plane, namely, that of it's ring, excepting the fifth, the plane of whoſe orbit deviates a little therefrom. Thoſe of Jupiter move alſo in a plane very nearly coincident with that in which Jupiter moves about the ſun.

The ſatellites, and their primaries, mutually eclipſe each other in the ſame manner in which it has been ſhewn that the earth and the moon do.

But

But there are three cafes in which the fatellites difappear to us.

The one is, when the fatellite is directly behind the body of it's primary, with refpect to the EARTH; this is called an OCCULTATION of the planet.

Another is, when it is directly behind it's primary, with refpect to the SUN, and fo falls into it's fhadow, and fuffers an eclipfe, as the moon, when the earth is interpofed between that and the fun.

The laft is, when it is interpofed between the earth and it's primary; for then it cannot be diftinguifhed from the primary itfelf.

It is not often that a fatellite can be difcovered upon the difc of Jupiter, even by the beft telefcopes, excepting at it's firft entrance, when by reafon of it's being more directly illuminated by the rays of the fun, than the planet itfelf, it appears like a lucid fpot upon it; fometimes however a fatellite is feen paffing over the difk like a dark fpot; this has been attributed to fpots on the furface of the fatellite, and that the more probably as the fame fatellite has been known to pafs over the difk at one time as a dark fpot, and at another time to be fo luminous as only to be diftinguifhed from the planet, at it's ingrefs and egrefs. The beginnings and endings of thefe eclipfes are eafily feen by a telefcope, when the planet is in a proper fituation;

but when it is in conjunction with the ſun, the brightneſs of that luminary renders both the planet and ſatellite inviſible.

By obſerving the eclipſes of Jupiter's ſatellites, it was diſcovered that light is not propagated inſtantaneouſly, though it moves with an incredible velocity; ſo that light reaches from the ſun to us in the ſpace of eleven minutes of time, at more than the rate of 100,000 miles in a ſecond.

The orbits of all the ſatellites of Saturn, except the fifth, are nearly in the ſame plane, which plane makes an angle with that of Saturn's orbit, of about 31°; this inclination is ſo great, that they cannot paſs either acroſs Saturn or behind it, with reſpect to the earth, except when they are very near their nodes, ſo that their eclipſes are not near ſo frequent as thoſe of Jupiter. An occultation of the fourth behind the body of Saturn has been obſerved, and Caſſini once ſaw a ſtar covered by the fourth ſatellite, ſo that for 13 minutes they appeared as one.

They are ſo minute as not to be viſible unleſs the air is exceeding clear; Caſſini obſerved the fifth ſatellite to diminiſh in ſize, as it went through the eaſtern part of it's orbit, until it became quite inviſible, while in the weſtern part it increaſed in brightneſs, until it arrived at it's greateſt ſplendor. In 1705 it was viſible in all parts of it's orbit, through the ſame teleſcopes

ſcopes that were often uſed before to diſcover it without ſucceſs.

The Georgium Sidus is attended by two ſatellites; the innermoſt is ſuppoſed to perform it's revolution in about eight days, ſeventeen hours; the ſecond in 13 days, eleven hours, it's diſtance 33″; the ſecond ſatellite at it's greateſt viſible elongation from it's planet, and at the mean diſtance of the Georgium from the earth, is 42″ 23‴, greateſt diſtance 44″ 23‴: the ſatellites are probably not leſs than thoſe of Jupiter; there will be eclipſes of them in 1799, and 1818.

OF THE FIXED STARS.

No part of the univerſe gives ſuch enlarged ideas of the ſtructure and magnificence of the heavens, as the conſideration of the number, magnitude, and diſtance of the fixed ſtars. We admire indeed, with propriety, the vaſt bulk of our own globe; but when we conſider how much it is ſurpaſſed by moſt of the heavenly bodies, what a point it degenerates into, and how little more even the vaſt orbit, in which it revolves, would appear, when ſeen from ſome of the fixed ſtars, we begin to conceive more juſt ideas of the extent of the univerſe, and of the boundaries of creation.

Among the many diſtinctions that characterize the fixed ſtars from the other luminaries of

heaven, that which is afforded by their light, or peculiar luſtre, is the moſt obvious.

The light of the planets is ſteady, becauſe it is reflected; that of the ſtars is bright and lively, and accompanied with a kind of vibration of light, which we call twinkling. This is ſuppoſed to ariſe from the nature of their light as intrinſic, and not received and reflected, and principally from the ſmallneſs of their apparent diameter. Our atmoſphere is full of innumerable little particles, which are continually floating in it; many of theſe are large enough, on coming between the eye and ſuch a point as a fixed ſtar, to hide that point, or take that ſtar out of our view, by intercepting it's rays. But theſe atoms are in perpetual motion, ſo that the ſtar is no ſooner hid by one of them, than it appears again, becauſe the atom has changed it's place; then another comes, and again intercepts the view: the ſwift ſucceſſion of theſe moving particles, greatly aſſiſts in cauſing that appearance which we term twinkling. Or, it may probably ariſe from ſomething in the eye itſelf, for we are continually ſhifting and cloſing them, even when we are not conſcious of doing it, and a ſtar being but a point, the ſmalleſt motion of the eye is ſufficient to make us loſe it; perhaps the impreſſions are ſo weak, as not to be able to keep the viſive faculty awake, except as it were by fits.

The

The moſt conſpicuous and brighteſt of the fixed ſtars of our horizon is Sirius. The earth, in moving round the ſun, is 190 millions of miles nearer to this ſtar in one part of it's orbit, than in the oppoſite; yet the magnitude of the ſtar does not appear to be in the leaſt altered, or it's diſtance affected by it; ſo that the diſtance of the fixed ſtars is great beyond all computation. The unbounded ſpace appears filled at proper diſtances with theſe ſtars, each of which is probably a ſun, with attendant planets rolling round it. In this view, what, and how amazing, is the ſtructure of the univerſe!

Though the fixed ſtars are the only marks by which aſtronomers are enabled to judge of the courſe of the moveable ones, and we have aſſerted their relative poſitions do not vary; yet this aſſertion muſt be confined within ſome limits, for many of them are found to undergo particular changes, and perhaps the whole are liable to ſome peculiar motion, which connects them with the univerſal ſyſtem of created nature. Dr. Herſchel even goes ſo far as to ſuppoſe that there is not, in ſtrictneſs of ſpeaking, one fixed ſtar in the heavens; but that there is a general motion of all the ſtarry ſyſtems, and conſequently of the ſolar one among the reſt.

There are ſome ſtars, whoſe ſituation and place were heretofore known, and marked with preciſion, that are no longer to be ſeen; new ones

have alſo been diſcovered, that were unknown to the ancients, while numbers ſeem gradually to vaniſh. There are others which are found to have a periodical increaſe and decreaſe of magnitude; and it is probable, that the inſtances of theſe changes would have been more numerous, if the ancients had poſſeſſed the ſame accurate means of examining the heavens, as are uſed at preſent.

New ſtars offer to the mind a phænomenon more ſurprizing, and leſs explicable, than almoſt any other in the ſcience of aſtronomy. I ſhall ſelect a few inſtances of the more remarkable ones, for the inſtruction of the young pupil: a conſideration of the changes that take place, at ſo immenſe a diſtance as the ſtars are known to be from him, may elevate his mind to conſider the immenſity of HIS power, who regulates and governs all theſe wide extended motions; "who hath meaſured the waters in the hollow of his hand, and meted out heaven with a ſpan."

"Who turns his eye, on nature's midnight face,
BUT MUST ENQUIRE——What hand behind the ſcene,
What ARM ALMIGHTY, put theſe wheeling globes
In motion, and wound up the vaſt machine?"

It was a new ſtar diſcovered by Hipparchus, the chief of the ancient aſtronomers, that induced him to compoſe a catalogue of the

fixed

fixed ſtars, that future obſervers might learn from his labours, whether any of the known ſtars diſappeared, or new ones were produced. The ſame motives engaged the illuſtrious Tycho Brahe to form, with unremitting labour and aſſiduity, another new catalogue of the ſtars.

Of new ſtars, the firſt of which we have a good account, is that which was diſcovered in the conſtellation Caſſiopea, in the month of November of the year 1572, a time when aſtronomy was ſufficiently cultivated, to enable the aſtronomers to give the account with preciſion. It remained viſible about ſixteen months; during this time, it kept it's place in the heavens, without the leaſt variation. It had all the radiance of the fixed ſtars, and twinkled like them; and was in all reſpects like Syrius, excepting that it ſurpaſſed it in brightneſs and magnitude. It appeared larger than Jupiter, who was at that time in his perigee; and was ſcarce leſs bright than Venus.

It was not by degrees that it acquired this diameter, but ſhone forth at once of it's full ſize and brightneſs, as if of inſtantaneous creation. It continued about three weeks in full and entire ſplendor, during which time it might be ſeen even at noon day, by thoſe who had good eyes, and knew where to look for it. Before it had been ſeen a month, it became viſibly ſmaller, and from thence continued diminiſhing in mag-

nitude till March, 1574, when it entirely diſappeared. As it decreaſed in ſize, it varied in colour; at firſt, it's light was white, and extremely bright; it then became yellowiſh, afterwards of a ruddy colour, like Mars; and finiſhed with a pale livid white, reſembling that of Saturn.

In 1596, Fabricius obſerved a new ſtar in the neck of the Whale: he firſt ſaw it in Auguſt, and it diſappeared in October of the ſame year. In 1637, Phocyllides Holwarda obſerved it again, and not knowing that it had been ſeen before, took it for a new diſcovery: he watched it's place in the heavens, and ſaw it appear again the ſucceeding year, nine months after it's diſappearance. It has been ſince found to be every year very regular in it's period, except that in 1672 it was miſſed by Hevelius, and not ſeen again till 1676. Bullialdus having compared together the obſervations which had been made of it from 1638 to 1666, determined the periodical time between this ſtar's appearing in it's greateſt brightneſs, and returning to it again, to be 333 days; obſerving further, that this ſtar did not appear at once in it's full magnitude, or brightneſs, but by degrees arrived at them. He alſo framed an hypotheſis, to account for theſe periodic changes.

Three changeable, or re-apparent ſtars, have been diſcovered in the conſtellation of the Swan; the

the firſt was ſeen by Janſonius, in 1600; the ſecond was diſcovered in 1670; the third by Kirchius, in 1686.

In the latter end of September, 1604, a new ſtar was diſcovered near the heel of the right foot of Serpentarius. There were in that part of the heavens, at that time, the three ſuperior planets, which ſo engaged the attention of aſtronomers, that no appearance thereabouts could have long eſcaped them. Kepler, in deſcribing it, ſays, that it was preciſely round, without any kind of hair, or tail; that it was exactly like one of the ſtars, except that in the vividneſs of it's luſtre, and the quickneſs of it's ſparkling, it exceeded any thing he had ever ſeen before. It was every moment changing into ſome of the colours of the rainbow, as yellow, orange, purple, and red; though it was generally white, when it was at ſome diſtance from the vapours of the horizon. Thoſe in general who ſaw it, agreed that it was larger than any other fixed ſtar, or even any of the planets, except Venus: it preſerved it's luſtre and ſize for about three weeks; from this time it grew gradually ſmaller. Kepler ſuppoſes that it diſappeared ſome time between October, 1605, and the February following, but on what day is uncertain.

Beſides theſe ſeveral re-apparent ſtars, ſo well characterized and eſtabliſhed by the earlieſt among the modern aſtronomers, there have been

many

many difcovered fince, by Caffini, Maraldi, and others; Mr. Montanere fpeaks of having obferved above one hundred changes among the fixed ftars.

The ftar Algol, in Medufa's head, has been obferved long fince to appear of different magnitudes, at different times. The period of it has been lately fettled by J. Goodrick, Efq. of York. It periodically changes from the firft to the fourth magnitude; the time employed from one greateft diminution to the other, was, anno 1783, at a mean 2 days, 20 hours, 49 minutes, 3 feconds. The changes are thus: during four hours it gradually diminifhes in luftre; during the fucceeding four hours, it recovers it's firft magnitude by a like gradual increafe; and during the remaining part of the period, namely, 2 days, 12 hours, 49 minutes, 3 feconds, it invariably preferves it's greateft luftre; after the expiration of which term, the diminution again commences.

The caufes of thefe appearances cannot be affigned at prefent, with any degree of probability; perhaps they have fome analogy to the fpots on the fun, which at fome times appear in greater numbers than at others, fome of them bigger than the whole earth; or perhaps they are owing to fome real motions of the ftars themfelves.

There are feveral ftars that appear fingle to the naked eye, which are, on examination with

a telefcope, found to confift of two, three, &c. The number of double ftars obferved before the time of Dr. Herfchel, was but fmall; but this celebrated aftronomer has noted upwards of four hundred; among thefe, fome that are double, others that are treble, double double, quadruple, double treble, and multiple; his catalogue gives the comparative fize of thefe ftars, their colour as they appeared to him, with feveral other very curious particulars.

HERSCHEL ON THE CONSTRUCTION OF THE UNIVERSE.

Before we leave the fubject of the fixed ftars, we fhall endeavour to give the reader an account of Dr. Herfchel's ideas of the conftruction of the univerfe. Former aftronomers had fuppofed that our fun, befides occupying the center of his own fyftem, was alfo the center of the univerfe; and that the fidereal heavens might be properly reprefented on the concave furface of a fphere: but thefe are ill adapted, fays the Doctor, for a delineation of the interior parts of the heavens. Being able to penetrate into thefe regions by means of large telefcopes,* we may now confider them as a naturalift regards a rich extent

* Mr. Herfchel's obfervations, on which this theory is founded, were made with a Newtonian reflector, of 20 feet focal length, and an aperture of 18 inches.

extent of ground, or a chain of mountains, containing STRATA varioufly INCLINED and DIRECTED, and compofed of very different materials. He gives ftrong reafons, deduced from a feries of obfervations, as well as confiderations, drawn from analogy, to prove that the vifible fyftem of nature, which we call THE UNIVERSE, confifting of all the celeftial bodies, and many more than can be feen by the naked eye, is only a group of ftars, or funs, with their planets, conftituting one of thofe patches called a nebula; and this is, perhaps, not one ten thoufandth part of the univerfe.

Mr. Herfchel found that his large telefcope completely refolved the whitifh appearance of the Via Lactea into ftars. Having viewed and guaged this bright zone in all directions, he found it compofed of fhining ftars, whofe number conftantly increafes and diminifhes, in proportion to it's apparent brightnefs to the naked eye. There is, fays he, no doubt but that the Milky Way is a moft extenfive ftratum of ftars of various fizes, and that our fun is one of the heavenly bodies belonging to it.

The portion of the Milky Way that he firft obferved, was that about the hand and club of Orion; here he found an aftonifhing multitude of ftars, which he attempted to number; by eftimating the number contained in the field of his telefcope at once, and computing from a mean

mean of theſe, how many might be contained in a given portion of the Milky Way, in the moſt vacant places, about that part, he found 63 ſtars; other ſix fields contained 110, 60, 70, 90, 70, and 74 ſtars; a mean of theſe gives 79 for the number of ſtars in each field: ſo that allowing 15 minutes for the diameter of his field of view, a belt of 15 degrees long, and 2 degrees broad, could not contain leſs than 50,000 ſtars, large enough to be diſtinctly numbered; beſides which, he ſuſpected twice as many more, which could be ſeen only now and then by faint glimpſes, for want of ſufficient light.

It is very probable that the great ſtratum, called the MILKY WAY, is that in which the ſun is placed, though not in the very center of it's thickneſs. This is gathered partly from the appearance of the galaxy, which ſeems to encompaſs the whole heavens, as it certainly muſt do, if the ſun is within the ſame. For, ſuppoſe a number of ſtars arranged between two parallel planes, infinitely extended every way, but at a given conſiderable diſtance from each other, and calling this a SIDEREAL STRATUM, an eye placed ſomewhere within it, will ſee all the ſtars in the direction of the planes of the ſtratum projected into a great circle, which will appear lucid, on account of the accumulation of the ſtars; while the reſt of the heavens, at the ſides, will only ſeem to be ſcattered over with conſtellations, more or

leſs

lefs crowded, according to the diftance of the planes, or numbers of the ftars, contained in the thicknefs or fides of the ftratum.

Thus in fig. 3, plate XIII. an eye at S within the ftratum *a, b,* will fee the ftars in the direction of it's length a b, or height c d, together with all thofe in the intermediate fituation, projected into the lucid circle A B C D; while thofe in the fides *me nw,* will be feen fcattered over the remaining part of the heavens at MVNW. Let us now fuppofe, that a branch, or fmaller ftratum, fhould run out from the former in a certain direction, and let it alfo be contained between two parallel planes, extended infinitely onwards, but fo that the eye may be placed in the greater ftratum, fomewhere before the feparation, but not far from the place where the ftrata are ftill united; this fecond ftratum will not be projected into a bright circle like the former, but will be feen as a lucid branch proceeding from the firft, and returning to it at a certain diftance lefs than a femicircle. Thus, in the fame figure, the ftars in the fmall ftratum p g, will be projected into a bright arch at PRRP, which after it's feparation from the circle, unites with it again at P.

If the eye were placed without the ftratum, but at no very great diftance, the appearance of the ftars within it would affume the form of one of the leffer circles of the fphere; which would be

be more or lefs contracted, according to the diftance of the eye: if this was exceedingly increafed, the whole ftratum might at laft be drawn into a lucid fpot of any fhape, according to the pofition, length, and height of the ftratum. What has been inftanced in parallel planes, may be eafily applied to ftrata irregularly bounded, and running in various directions; and thus any kind of curvatures, as well as various degrees of brightnefs, may be produced in the projection.

From appearances, we may infer, that the fun is placed in one of the great ftrata of the fixed ftars, and very probably not far from the place where fome fmaller ftratum branches out from it. Such a fuppofition accounts for all the phenomena of the Milky Way with great eafe and fimplicity, while every ftar in the ftratum will have it's own galaxy, with only fuch variations in form and luftre, as may arife from their particular fituation.

There is, fays Dr. Herfchel, a remarkable clearnefs and purity in the heavens, when we look out of our ftratum at the fides, that is, towards Leo, Virgo, and Coma Berenices, on one fide, and towards Cetus on the other; whereas the ground of the heavens becomes troubled, as we approach towards the length or height of it. Thefe troubled appearances are eafily to be explained, by afcribing them to fome of the diftant ftraggling ftars, that hardly yield light enough

enough to be diftinguifhed; but when we look towards the pole of our fyftem, where the vifual ray does not graze along the fide, the ftraggling ftars of courfe will be very few in number, and therefore the ground of the heavens will appear much purer and more clear.

Mr. Herfchel points out the methods whereby the fun's place in the fidereal ftratum may be afcertained, but thefe demand more previous knowledge than is to be fuppofed in the readers of an introductory work like the prefent. After this, he lays down fome fuppofitions on the fubject, taking a point of view at a very remote period of time, and an immenfe diftance of fpace; thefe for the fame reafon we fhall leave untouched, and proceed to his view of the heavens from our own retired ftation, in one of the planets, attending to a ftar in it's great combination with numberlefs others; and in order to inveftigate what will be the appearances from this contracted fituation, let us begin with the naked eye.

The ftars of the firft magnitude, being in all probability the neareft, will furnifh us with a ftep to begin the fcale. Setting off, therefore, with the diftance of Sirius or Arcturus; for inftance, as unity, we fhall at prefent fuppofe, that thofe of the fecond magnitude are at double, thofe of the third at treble the diftance, &c. Taking it for granted, then, that a ftar of the feventh

 magni-

magnitude (the ſmalleſt viſible to the naked eye) is about ſeven times as far as one of the firſt. It follows, that an obſerver who is incloſed in a globular cluſter of ſtars, and not far from the center, will never be able, by his naked eye, to ſee to the end of it; for ſince, according to the foregoing eſtimations, he can only extend his view to about ſeven times the diſtance of Sirius, it cannot be expected that his eyes ſhould reach the borders of a cluſter, which has perhaps no leſs than 50 ſtars in depth every where around him. The whole univerſe therefore, to an obſerver confined to unaſſiſted viſion, will be comprized in a ſet of conſtellations richly ornamented, with ſcattered ſtars of all ſizes. Or, if the united brightneſs of a neighbouring cluſter of ſtars ſhould, in a remarkably clear night, reach his ſight, it will put on the appearance of a ſmall, faint, whitiſh nebulous cloud, not to be perceived without the greateſt attention. Let us ſuppoſe him placed in a much extended ſtratum, or branching cluſter of millions of ſtars: here the heavens will not only be richly ſcattered over with brilliant conſtellations, but a ſhining zone or milky way will be perceived to ſurround the whole ſphere of the heavens, owing to the combined light of the ſtars that are too remote to be ſeen; our obſerver's ſight will be ſo confined, that he will imagine this ſingle collection of ſtars, though he does not perceive the thou-

ſandth part of them, to be the whole contents of the heavens. Allowing him now the uſe of a common teleſcope, he begins to ſuſpect that all the milkineſs of the bright path, which ſurrounds the ſphere, may be owing to ſtars: he perceives a few cluſters of them in various parts of the heavens, and finds alſo that there is a kind of nebulous patches, but ſtill his views are not extended to reach ſo far as to the end of the ſtratum in which he is ſituated; ſo that he looks upon theſe patches as belonging to that ſyſtem which, to him, ſeems to comprehend every celeſtial object. It now increaſes his power of viſion; and applying himſelf to a cloſe obſervation, finds that the Milky Way is indeed no other than a collection of very ſmall ſtars: he perceives that thoſe objects which had been called nebulæ, are evidently nothing but cluſters of ſtars; their number increaſes upon him; and whilſt he reſolves one nebula into ſtars, he diſcovers ten new ones that he cannot reſolve. He then forms the idea of immenſe ſtrata of fixed ſtars, of cluſters of ſtars, and of nebulæ, till going on with ſuch intereſting obſervations, he ſoon finds that all theſe appearances ariſe from the confined ſituation in which we are placed. CONFINED it may be juſtly called, though contained in no ſmaller a ſpace than what appeared before to be the whole region of fixed ſtars, but which now has aſſumed the ſhape of a crookedly

branching

branching nebula; not one of the leaſt, but probably very far from being the moſt conſiderable, of thoſe numberleſs cluſters that enter into the conſtruction of the heavens. Dr. Herſchel confirms theſe ideas by a ſeries of obſervations, and thinks it will be found upon the whole, that this view, with all it's conſequential appearances, as ſeen by an eye incloſed in one of the nebulæ, is no other than a drawing from nature, wherein the features of the original have been cloſely copied; and Dr. Herſchel hopes the reſemblance will not be called a bad one, when it ſhall be conſidered how very limited muſt be the pencil of an inhabitant of ſo ſmall and retired a ſpot of an indefinite ſyſtem, in attempting the picture of ſo unbounded an extent.

In the moſt crouded parts of the Milky Way, he has had a field of view of 588 ſtars, and theſe continued for many minutes; ſo that in one quarter of an hour's time, not leſs than 116,000 ſtars have paſſed through the field of his teleſcope: he endeavours to ſhew, that the powers of his teleſcope are ſuch, that it will not only reach the ſtars at 497 times the diſtance of Sirius, ſo as to diſtinguiſh them, but that it alſo ſhews the united luſtre of the accumulated ſtars that compoſe a milky nebuloſity at a far greater diſtance. From theſe conſiderations, it is highly probable, that as his 20 feet teleſcope does not ſhew ſuch a nebuloſity in the Milky

Way, goes already far beyond it's extent, and therefore a more powerful inſtrument would remove all doubt, by expoſing a milky nebuloſity beyond the ſtratum, which could then no longer be miſtaken for the dark ground of the heavens.

To the foregoing arguments, we may add the following, drawn from analogy; Dr. Herſchel ſays, that among the great number of nebulæ which he has already ſeen, amounting to more than 900, there are many, in all probability, equally extenſive with that which we inhabit; and yet they are all ſeparated from each other by very conſiderable intervals. Some, indeed, there are, that ſeem to be double and treble; and though with moſt of them it may be, that they are at a very great diſtance from each other, yet he does not mean to ſay that there are no ſuch conjunctions; though there may be alſo ſome thinly ſcattered ſolitary ſtars, not yet drawn into ſyſtems; their number cannot be very conſiderable: a conjecture that is abundantly confirmed, in ſituations where the nebulæ are near enough to have their ſtars viſible; for they are all inſulated, and generally to be ſeen upon a very clear and pure ground, without any ſtar near them, that might be ſuppoſed to belong to them: and though they may be often ſeen in beds of ſtars, yet from the ſize of theſe ſtars, we may be certain that they are much nearer to us than thoſe nebulæ, and belong undoubtedly to our own ſyſtem.

The Origin of Nebulous Strata.

Dr. Herſchel thinks the nebula that we inhabit, has fewer marks of profound antiquity upon it than the reſt; having previouſly ſuppoſed that the condenſation of cluſters of ſtars is to be aſcribed to a gradual approach; the number of ages that muſt have paſt before ſome of the cluſters could be ſo far condenſed as they are at preſent, makes him naturally aſcribe a certain air of youth and vigour to many very regularly ſcattered regions of our ſidereal ſyſtem. There are many places, where he aſſerts that there is reaſon to believe, that the ſtars, if we may judge from appearances, are now drawing towards various ſecondary centers, and will, in time, ſeparate into different cluſters, ſo as to occaſion many ſub-diviſions. Our ſyſtem. after numbers of ages, may be divided ſo, as to give riſe to a ſtratum of two or three hundred nebulæ.

An Opening in the Heavens.

Some parts of our ſyſtem ſeem to have already ſuſtained greater ravages from time than others: in the body of the ſcorpion, there is an opening, or hole, which is probably owing to this cauſe; it is 4 degrees broad.

A PERFORATED NEBULA, OR RING OF STARS.

Among the curiofities of the heavens, fhould be placed a nebula that has a regular concentric dark fpot in the middle, and is probably a ring of ftars; it is of an oval fhape; in the northern fide 3 very faint ftars may be feen, as alfo one or two in the fouthern: the vertices of the longer axis feem lefs bright, and not fo well defined as the reft.

PLANETARY NEBULÆ.

Thefe are fo named from a fingularity of appearance, which renders it difficult to clafs them. Their light is fo uniform and vivid, the diameters fo fmall and well defined, as make it improbable that they fhould be common nebulæ: if nebulæ, they muft be compreffed, and condenfed in the higheft degree.

Though the words CONDENSATION and CLUSTER often occur in the foregoing extract, we are by no means to infer that any of the celeftial bodies, in our nebula, are nearer to one another than we are to Sirius, whofe diftance is fuppofed to be not lefs than 38 millions of millions of miles. The whole extent of the nebula being, in fome places, near 500 times this diftance, muft be fuch, that the light of a ftar placed at it's extreme boundary, fuppofing it to fly with the velocity

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of 12 millions of miles every minute, muſt have taken near 3000 years before it could reach us.

Theſe immenſe ſpaces, theſe numerous hoſts of ſyſtematic univerſes, are probably connected the one with the other. Like ſo many immenſe circuſes, by the mutual contact of their circumambient ſpheres, they preſs each other: theſe aereal atmoſpheres being alſo connected and interwoven together by an infinity of inſertions, conſtitute a celeſtial ſphere, which is again linked with others, till by an infinity of orbs they obtain a form, which is the origin and pattern of all forms, in which all the variegated ſidereal revolutions harmoniouſly concur to one and the ſame end; that of mutually ſtrengthening and eſtabliſhing each other, and forming a celeſtial union.

OF THE TELESCOPIC APPEARANCE OF THE PLANETS.

"The obſervations which might with fullneſs of evidence confirm the opinion of planetary worlds, ſeem to be placed out of our reach, and we can ſcarce hope to make our optical inſtruments ſufficiently perfect, to render the inhabitants thereof viſible to us. All, therefore, that we can do, is to examine if the planets are accommodated with thoſe things which we are uſed to conſider as neceſſary to animal exiſtence. Lands, ſeas, clouds, vapours, and an atmoſphere,

or body of air, are objects that we may expect to find on the face of an habitable world."

By means of the telefcope, we are enabled, in fome meafure, to afcend into the celeftial region, and view the fun, moon, and ftars, as they would appear to us if they were brought fo many times nearer to us as the telefcope magnifies; the light proceeding from the luminary we are looking at, being diminifhed in the fame proportion.

The telefcope is one of thofe difcoveries, of which no idea could have been formed, previous to the period in which the Supreme Being was pleafed to unveil to the human mind fome of the myfterious powers of glafs: the importance of this difcovery, and the extent to which it may be carried, ftill lie hid among the fecrets of infinite wifdom. It is by this inftrument more than by any other, that we have been led onward in our advances towards a perfect knowledge of the heavenly bodies, and that aftronomy has been raifed from little more than a catalogue of ftars, into a fcience.

When we look at the fun through a telefcope even of moderate power, the eye being defended by a piece of coloured or fmoked glafs, nay, even by the naked eye, when guarded in the fame manner, we difcover on his furface many black, or rather lefs bright fpots, of various fizes and fhapes. Sometimes thefe fpots will vanifh in a

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a very ſhort time after their firſt appearance; ſometimes they travel over his whole diſk, or viſible ſurface, from weſt to eaſt, when they diſappear, and in twelve or thirteen days they appear again, ſo as to be known, by their magnitude and figure, to be thoſe that had diſappeared before. Thoſe, however, which are of the longeſt continuance, do not appear to have much ſolidity of conſiſtence, for in a little time they alſo vaniſh, and become bright like the reſt of the ſurface.

The ſpots are more frequent at ſome periods than at others; in ſome years, the ſun's diſk has for many months been perfectly free from them; in others, he has for months been more or leſs obſcured by ſpots: the moſt remarkable phænomena of theſe ſpots, as obſerved by Scheiner and Hevelius, are as follow: 1. Every ſpot, which has a nucleus, or dark part, hath alſo an umbra, or fainter ſhade, ſurrounding it. 2. The boundary betwixt the nucleus and umbra is always diſtinct and well-defined. 3. The increaſe of a ſpot is gradual, the breadth of the nucleus and umbra dilating at the ſame time. 4. In like manner, the decreaſe of a ſpot is gradual, the breadth of the nucleus and umbra diminiſhing at the ſame time. 5. The exterior boundary of the umbra never conſiſts of ſharp angles, but is always curvilinear, how irregular ſoever the outſide of the nucleus may be. 6. The nucleus of a

ſpot,

ſpot, whilſt on the decreaſe, often changes it's figure, by the umbra incroaching irregularly upon it, inſomuch that in a ſmall ſpace of time new incroachments are diſcernible, whereby the boundary between the nucleus and the umbra is perpetually varying. 7. It often happens, that by theſe incroachments the nucleus of a ſpot is divided into two or more nuclei. 8. The nuclei of the ſpots vaniſh before the umbra. 9. Small umbræ are often ſeen without nuclei. 10. A large umbra is ſeldom ſeen without a nucleus in the middle of it. 11. When a ſpot, which conſiſted of a nucleus and an umbra, is about to diſappear, if it be not ſucceeded by a facula, or ſpot, brighter than the reſt of the diſk, the place it occupied is in a very little time not to be perceived.

In the Philoſ. Tranſ. vol. lxiv. the reader will find ſeveral curious obſervations on theſe ſpots, by Profeſſor Wilſon, and the Rev. Mr. Wolaſton. The latter gentleman ſays, he once ſaw, with a twelve-inch reflector, a ſpot burſt to pieces, while he was looking at the ſun ; the appearance was to him as that of a piece of ice, when daſhed on a frozen pond, which breaks to pieces, and ſlides in various directions.

The ſpots are by no means confined to one part of the ſun's diſk, though we do not know that any have been obſerved about his polar regions. Though their direction is from eaſt to weſt, yet

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the paths they deſcribe in their courſe over the diſk, are exceedingly different, ſometimes being in ſtrait lines, ſometimes in curves; at one time deſcending from the northern to the ſouthern part of the diſk, at other times aſcending from the ſouthern to the northern part.

The larger ſpots, moſt of which exceed the whole earth in apparent magnitude, laſt a conſiderable time, ſometimes three months before they diſappear, at which time they are generally converted into ſpots exceeding the reſt of the ſun in brightneſs. The general opinion concerning their nature is, that they are volcanoes, or burning mountains of immenſe ſize; and that when the eruption is nearly ended, and the ſmoke diſſipated, the fierce flames are expoſed, and appear as luminous ſpots. D. Wilſon ſuppoſes them, on the other hand, to be excavations in the luminous matter (or atmoſphere) that environs the body of the ſun.

The diameter of a ſpot near the middle of the diſk, is meaſured by comparing the time it takes in paſſing over a croſs hair in a teleſcope, with the time wherein the whole diſk of the ſun paſſes over the ſame hair. It may alſo be meaſured by a micrometer. Hevelius obſerved a ſpot that roſe, and vaniſhed, in 16 or 17 hours. None have been obſerved to continue longer than 70 days.

When we look at THE MOON with the naked

eye,

eye, we difcern a great number of irregular fpots on her difk, diftinguifhed by their dark colour from the brighter or more glaring parts; but when viewed through a telefcope, their number is prodigioufly increafed; and it is perceived, that many of thefe appearances are occafioned by vaft obfcure pits or cavities, and elevations or mountains. The fpots in the moon always keep their places, not being moveable like thofe of the fun. Sometimes more or lefs, of the northern, and fouthern, and eaftern, and weftern, part of the difk is feen, which is owing to what is called her libration.

Thefe mountains and cavities are known to be fuch, from the fhadow they caft. In the firft and fecond quarters, when the light of the fun falls obliquely upon them, the elevated parts caft a triangular fhadow on the fide oppofite to the fun; whereas, with refpect to the cavities, thefe have that fide which is oppofite to the fun illuminated, and that which is next the fun is dark and obfcure, the fame as would happen to a hollow bafon, placed on a table at fome diftance from a candle, in a room where there is no other light. The fhadows fhorten as the fun becomes more directly oppofed to the anterior face of the moon, and at length difappear at the time of the full. During the third and laft quarters, the fhadows appear again, but all fall towards the contrary

fide

ſide of the moon, though ſtill with the ſame diſtinction, namely, that the mountains are dark and ſhady on the ſide fartheſt from the ſun, and the pits are dark on the ſide next the ſun.

The full moon is a very pleaſing ſight through a teleſcope, and has a great variety of luſtre and colour; but it is not the face on which to diſcover the mountains, theſe are beſt ſeen at the increaſe or decreaſe; for beſides the evidence derived from the ſhadows, we may then ſee the tops of theſe mountains catching the rays of the ſun before they reach that part of the ſurface on which their bottoms are placed.

On April 19, 1787, Dr. Herſchel obſerved ſome appearances on the ſurface of the moon, which, judging by analogy from things perceived here with us, he thought he might term volcanoes. Three of theſe he obſerved in different places of the dark part of the moon; two of them appeared nearly extinct, or going to break out; the third, as an actual eruption of fire, or luminous matter. On the 20th it burnt with greater violence, and might be computed to be about three miles in diameter; the eruption reſembled a piece of burning charcoal, covered by a thin coat of white aſhes; all the adjacent parts of the volcanic mountain were faintly illuminated by the eruption, and were gradually more obſcure as they lay at a greater diſtance from the crater. Dr. Herſchel had, in 1783, obſerved

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an eruption, ſomewhat ſimilar to that of the foregoing volcano. Indeed an appearance of this kind had been ſeen before, by Don Ulloa, in an eclipſe of the ſun. It was a ſmall bright ſpot, near the margin of the moon, which he ſuppoſed to be a hole with the ſun's light ſhining through it.

That the moon is ſurrounded by an atmoſphere, is rendered probable by many obſervations of the ſolar eclipſes, in which the edge or limb of the ſun was obſerved to tremble juſt before the beginning. The planets are likewiſe obſerved to change their figure from round to oval, juſt before the beginning of an occultation behind the moon, which can be attributed to no other cauſe than that their light is refracted by being ſeen through the moon's atmoſphere. That we ſee no clouds, will not appear ſurprizing, if we conſider that the lunar days and nights are thirty times as long as our's; it will be eaſy to conceive, that with them the phænomena of vapours may be very different from what they are with us; perhaps their clouds and rain, if any, may be condenſed into viſible quantities only during the abſence of the ſun, and of courſe when they muſt be inviſible to us.

Mercury being at all times near the ſun, we can only diſtinguiſh by the teleſcope a variation of his figure, which is ſometimes

that

that of a half moon, ſometimes a little more or leſs than half.

Venus, when in the form of a creſcent, and at her brighteſt times, affords a more pleaſing teleſcopic view than any other of the heavenly bodies; her ſurface is diverſified with ſpots, like thoſe of the moon; by the motion of theſe, the time ſhe takes up in revolving upon her axis is diſcovered. With a powerful teleſcope, mountains like thoſe in the moon may be ſeen.

Mars appears always round and full, except at the time of the quadrature, when it's diſk appears like that of the moon about three days after the full. By the ſpots which are ſeen on it's ſurface, it's diurnal revolution has been aſcertained. From it's characteriſtic ruddineſs, and from other phænomena, it has been ſuppoſed that it's atmoſphere is nearly of the ſame denſity with our's. Dr. Herſchel has obſerved two white luminous circles ſurrounding the poles of this planet; theſe are ſuppoſed to ariſe from the ſnow lying about thoſe parts.

The appearance of Jupiter through a teleſcope, opens a vaſt field for ſpeculative inquiry. The ſurface is not equally bright, but is diſtinguiſhed by certain bands, or belts, of a duſkier colour than the reſt of the ſurface, running parallel to each other, and to the plane of it's orbit. They are

are not regular or conſtant in their appearance; ſometimes only one is ſeen, at other times eight have been ſeen; their breadth is likewiſe variable, one belt growing narrow while another in it's neighbourhood becomes broader, as if one had flowed into the other; in this caſe an oblique belt has been obſerved to lie between them as if for the purpoſe of forming a communication. Sometimes one or more ſpots are formed between the belts, which increaſe till the whole is united in one large duſky band. There are alſo bright ſpots to be diſcovered on Jupiter's ſurface; theſe are rather more permanent than the belts, and re-appear after unequal intervals of time. The remarkable ſpot, by whoſe motion the rotation of Jupiter on his axis was aſcertained, diſappeared in 1694, and was not ſeen again till 1708, when it re-appeared exactly in the ſame place, and has been occaſionally ſeen ever ſince. The diſappearance and re-appearing of the ſpots is not ſo wonderful as the changes that have been obſerved in the belts; the elder Caſſini ſaw one evening five belts upon the planet, but while he was viewing them, they underwent the moſt ſurprizing change. In an hour from their fulleſt appearance there remained only three out of five, and one of theſe ſcarce perceptible. The moſt remarkable teleſcopic appearance of this planet, are the ſatellites, but theſe are particularly deſcribed under the head of SATELLITES.

Though

Though the great diftance of the planet Saturn, and the tenuity of it's light, do not permit us to diftinguifh the varieties of it's furface; yet fome of the firft difcoveries made by the telefcope were on this planet, and the ring is ftill one of the moft curious phænomena we are acquainted with. There is not, indeed, any thing in the whole fyftem of nature more wonderful than this ring, which appears nearly as bright as any part of the furface of the planet: by what means it is fufpended, or by what law fupported; whether it is only a bright but permanent cloud, or whether it is a vaft number of fatellites difpofed in the fame plane, whofe blended light gives it to us the form of one continual body, we can only form crude conjecture. M. Meffier has obferved on the anfes of this ring, feveral luminous white twinkling points, differing in vivacity from each other.

Sometimes our eye is in the plane of the ring, and then it becomes invifible: as it's plane always keeps parallel to itfelf, it difappears twice in every revolution of the planet, that is, about once in 15 years; and he fometimes appears quite round for nine months together. At other times the diftance betwixt the body of the planet and the ring is very perceptible, infomuch that Dr. Clarke's father faw a ftar through the opening. When Saturn appears round, if our eye be in the

plane of the ring, it will appear as a dark line across the middle of the planet's disk; if the eye be elevated above the plane, a shadowy belt will be visible; when the plane appears, the ring next the body is the brightest; when the ring appears of an elliptical form, the parts about the ends of the largest axis are called ansæ. These, a little before and after the disappearing of the ring, are of unequal magnitude. It has been supposed that the ring has a rotation round an axis.

With very long telescopes two belts have been discovered on Saturn, which appear parallel to that formed by the edge of the ring; these are said to be permanent: Cassini and Fatio perceived a bright streak upon Saturn which was not permanent, being visible one day, disappearing the next, when another came into view near the edge of his disk. Besides these there are it's five satellites mentioned under their proper head.

Of Comets.

Comets are a kind of stars, appearing at unexpected times in the heavens, and of singular and various figures, descending from far distant parts of the system, with great rapidity, surprizing us with the singular appearance of a train, or tail; and after a short stay, are carried off to distant regions, and disappear.

They

They were imagined in ancient times to be prodigies hung out by the immediate hand of God in the heavens, and intended to alarm the world. Their nature being now better underſtood, they are no longer terrible. But as there are ſtill many who think them to be heavenly warnings, portents of future events, it may not be improper for the tutor to inform his pupil, that the Architect of the univerſe has framed every part according to divine order, and ſubjected all things to laws and regulations: that he does not hurl at random ſtars and worlds, and diſorder the ſyſtem of the whole glorious frame, to produce falſe apprehenſions of diſtant events, fears without foundation, and without uſe. Religion glories in the teſt of reaſon, of knowledge, and of true wiſdom; it is every way connected with, and is always elucidated by them. From philoſophy we may learn, that the more the works of the Lord are underſtood, the more he muſt be adored; and that his ſuperintendancy over every portion is more clearly evinced, and more fully expreſſed by their unvaried courſe, than by ten thouſand deviations.

The exiſtence of an univerſal connection between all the parts of nature is now generally allowed. Comets undoubtedly form a part of this great chain; but of the part they occupy, and of the uſes for which they exiſt, we are equally ignorant. It is a portion of ſcience whoſe

perfection is reserved for some distant day, when these bodies and their vast orbits may, by long and accurate observation, be added to the known parts of the solar system; when astronomy will appear as a new science, after all our discoveries, great as we at present imagine them to be.

The astronomy of comets is very imperfect; for but little can be known with certainty, where but little can be seen. Comets afford few observations on which to ground conjecture, and are for the greatest part of their course beyond the reach of human vision; but that they are not meteors in the air is plain, because they rise and set in the same manner as the moon and stars; they are called comets, from their having a long tail somewhat resembling the appearance of hair; some however have appeared without this appendage, as well defined and round as planets.

It is generally supposed, that they are planetary bodies, making part of our system, revolving round the sun in extremely long elliptic curves; that as the orbit of a comet is more or less excentric, the distance to which they recede from the sun will be greater or less. Very great difference has been found by observation in this respect, even so great, that the sides of the elliptic orbit in some cases degenerate almost into right lines. They are very numerous; 450 are supposed to belong to our solar system.

That

That thoſe comets which go to the greateſt diſtance from the ſun, approach the neareſt to him at their return.

Their motions in the heavens are not all direct, or according to the order of the ſigns, like thoſe of the other planets. The number of thoſe which move in a retrograde manner, is nearly equal to thoſe whoſe motion is direct.

The orbits of moſt of them are inclined in very large angles to the plane of the ecliptic.

The velocity with which they move is variable in every part of their orbit; when they are near the ſun, they move with incredible ſwiftneſs; when very remote from him, their motion is inconceivably ſlow.

When they appear, they come in a direct line towards the ſun, as if they were going to fall into his body; and after having diſappeared for ſome time, in conſequence of his extreme brightneſs, they fly off on the other ſide as faſt as they came, continually loſing their ſplendor, till at laſt they totally diſappear. Their apparent magnitude is very different, ſometimes ſeeming not bigger than the fixed ſtars, at other times equal in diameter to Venus. Hevelius obſerved one in 1652, which was not inferior to the moon in ſize, though not ſo bright; it's light pale and dim, it's aſpect diſmal.

A greater number of comets are ſeen in the hemiſphere towards the ſun, than in the oppo-

ſite; and are generally inviſible at a ſmaller diſtance than that of Jupiter. Mr. Brydone obſerved one at Palmero, in July 1770, which, in 24 hours, deſcribed an arch in the heavens upwards of 50 degrees in length; ſo that if it was far diſtant from the ſun, it muſt have moved at the rate of upwards of 60 millions of miles in a day.

They differ alſo in form from the other planets, conſiſting of a large internal body, which ſhines with the reflected light of the ſun, and is encompaſſed with a very large atmoſphere, apparently of a fine matter, much reſembling that of the Aurora Borealis; this is called the head of the comet, and the internal part the nucleus. When a comet arrives at a certain diſtance from the ſun, an exhalation ariſes from it, which is called the tail.

The tail is always directed to that part of the heavens which is directly or nearly oppoſite to the ſun, and is greater, and brighter, after the comet has paſſed it's perihelium, than in it's approach to it; being greateſt of all when it has juſt paſt the perihelium. The tail of the comet of 1680 was of a prodigious ſize, extending from the head to a diſtance ſcarcely inferior to that of the ſun from the earth.

No ſatisfactory knowledge has been acquired concerning the cauſe of that train of light which accompanies the comets. Some philoſophers

imagine that it is the rarer atmoſphere of the comet impelled by the ſun's rays. Others, that it is the atmoſphere of the comet, riſing in the ſolar atmoſphere by it's ſpecific levity; while others imagine that it is a phænomenon of the ſame kind with the aurora borealis; and that this earth would appear like a comet to a ſpectator placed in another planet.

The number of the comets is certainly very great, conſiderably beyond any eſtimation that might be made from the obſervations we now poſſeſs.

There are, * who do not think the preſent aſtronomy of comets well eſtabliſhed; and that as ſo many ſmall ones are frequently ſeen, they think that nothing can be determined with certainty, till ſome better marks are diſcovered for diſtinguiſhing one from another, than any at preſent known; and that even the accompliſhment of Dr. Halley's prediction is uncertain: for it is very ſingular, that out of four years, in which three comets appeared, the only one, in which no comet was to be ſeen, ſhould be that very year in which the greateſt aſtronomers that ever exiſted had foretold the appearance of one; and in accounting for it's non-appearance, Mr. Clairault would have been equally ſupported by cometic evidence; whether he had concluded

* Encyclopædia Britannica, vol. 2. p. 765. Second Edition.

the comet to have been retarded or accelerated by the action of Jupiter and Saturn: a comet appeared in 1757, as well as in 1755, and had he determined the retardation of the comet to be twice as great as he did, another appeared in 1760 to have verified his calculations.

Of a Plurality of Worlds.

The fixed ſtars are generally ſuppoſed to be of the ſame nature with our ſun, each of them attended by planets, which are inhabited by rational creatures like this earth.

Inſtead, therefore, of one ſun, and one world, we find that the region of unbounded ſpace is peopled with ſuns, and ſtars, and worlds. This opinion has been held and taught by many of the moſt celebrated philoſophers and aſtronomers, both in ancient and modern times: in this view of things, our ſyſtem reſembles a ſingle individual of ſome one ſpecies of being in outward nature, diverſified from all it's fellow individuals, by differences uneſſential to the kind and ſpecies; but which conſtitute that beauty, which ariſes from uniformity amidſt variety.

That the fixed ſtars are ſuns, ſhining by their own light, is probable, on account of their immenſe diſtance from us; for as it is impoſſible that at theſe diſtances they could be ſeen by any reflection of light from the ſun, it is natural to ſuppoſe them endowed with a power of emitting light

light from their own bodies. By comparing the apparent diameter of objects at different diſtances, it is clear that our ſun would appear like a ſtar, were he removed to the diſtance at which they are placed; and that therefore it is truly reaſonable to ſuppoſe, that the fixed ſtars are equal, if not ſuperior in magnitude, to that which is the center of our ſyſtem; and that they are made for the ſame purpoſes with the ſun, to beſtow light, heat, and vegetation, on a certain number of planets revolving round them.

Of their immenſe diſtance from us, and the vaſtneſs of the ſpace they occupy, the reader may form ſome idea, when he is told, that numbers amongſt them are at too great a diſtance to be adequately expreſſed by figures, and beyond the reach of admeaſurement; and this will be heightened, if he conſiders that the ſmalleſt of the ſtars viſible to the eye are much more remote than the larger ones, and that the teleſcope diſcovers ſtars which are too diſtant to be perceptible to the naked eye. That the inſtrument, like our eyes, has it's limits; but the extent of the heavens has no bounds.

The fixed ſtars being ſo far removed from, and for the moſt part inviſible to us; it can ſcarcely be conceived by the narroweſt mind, that they form a part of our ſyſtem, or were created only to give a faint glimmering light to the inhabitants of this globe; for one additional moon would have

have afforded us more light than the whole hoſt of ſtars; ſuch an opinion is unworthy of our reaſon, inadequate to our conceptions of the Deity. It would be alſo abſurd to ſuppoſe that the author of nature had made ſo many ſuns without planets, to be enlightened by their light, and vivified by their heat; but more ſo, to imagine ſo many habitable worlds enlightened by ſuns without inhabitants; we may, therefore, ſafely conclude, that all the planets, of every ſyſtem, are inhabited.

This reaſoning is ſtill further ſtrengthened, by conſidering the immenſity of the ſtarry heavens, in which are innumerable hoſts of ſtars, created as the means to ſome great end. From revelation we learn, that the ultimate end of creation is the peopling of heaven with men. Theſe reſplendent ſuns are clearly then the mediums of exiſtence to ſo many earths, and of men upon them, created to be happy eternally with their God, "THE ONE ETERNAL THIRST TO BLESS." "Every ſtar is thus the center of a magnificent ſyſtem, attended by a retinue of worlds, irradiated by it's beams, and revolving round by it's active influence." Thus the greatneſs of God is magnified, and the grandeur of his empire made manifeſt. He is not glorified on one earth, or in one world, but in ten thouſand times ten thouſand. "If we could wing our way to the higheſt apparent ſtar, we ſhould there ſee other ſkies expanded,

expanded, other funs that diftribute their inexhauftible beams of day; other ftars, that gild the alternate night, and other (perhaps nobler) fyftems eftablifhed in unknown profufion, through the boundlefs dimenfions of fpace. Nor does the dominion of the Sovereign of all things terminate here; even at the end of this vaft tour we fhould find ourfelves advanced no further than the frontiers of creation, the commencement of the great JEHOVAH's kingdom.*

This mode of reafoning applies with greater force to the planets of our own fyftem, and gains additional ftrength from other confiderations. For who would venture to affert, that infinite love and confummate wifdom had formed fuch immenfe material maffes, fome of which exceed our earth in fize, convey them in revolutions round the fun, furnifh them with moons, grant them the alternate changes of night and day, viciffitudes of feafons, and all this only to emit their fcanty light on our earth.

Or who that has feen any engine, a windmill for inftance, and who knows the ufe of it, if he travels into another country, and there fees an engine of the fame fort, will not reafonably conclude that it is defigned for the fame purpofe? So when we know that the ufe of this planet, the earth, is for an habitation of various forts of animals, and we fee other planets at a diftance from

* Hervey's Meditations.

from us, ſome bigger, ſome leſs than the earth, moving periodically round, revolving on their axes, and attended with moons; is it not highly reaſonable to conclude, that they are all deſigned for the ſame uſe as this earth is, and that they are habitable worlds like that we live in?

"Who can conceive them
————————— unpoſſeſs'd
By living ſoul, deſert and deſolate,
Only to ſhine, yet ſcarce to contribute
Each orb a gleam of light?"

Or that the ALMIGHTY, who has not left with us a drop of water unpeopled, who has in every inſtance multiplied the bound of life, ſhould leave ſuch immenſe bodies deſtitute of inhabitants? It is ſurely much more rational to ſuppoſe them the poſſeſſion of human beings, beings formed with capacities for knowing, loving, and ſerving their Almighty Creator; bleſt and provided with every object conducive to their happineſs, and many of them in a far greater ſtate of purity than the inhabitants of our earth, and therefore in poſſeſſion of higher degrees of bliſs, and placed in ſituations, furniſhing them with ſcenes of joy, equal to all that poetry can paint, or religion promiſe: all under the direction, indulgence, and protection of infinite wiſdom and goodneſs.*

A com-

* See the Rev. Mr. Woolaſton's Reflexions, which are inſerted at the end of the Deſcription of the Celeſtial Globe, one of the ſubſequent ſubjects of theſe Eſſays.

A COMPREHENSIVE SURVEY OF THE UNIVERSE.

As this work is principally intended for young minds, the following view of the univerſe, by the amiable philoſopher of Geneva, Mr. Bonnet, cannot but prove acceptable to the reader, not only becauſe it will ſerve as a recapitulation of what has gone before, but as it will tend to enlarge his ideas, and increaſe his veneration for the Father of all beings.

When the ſhades of night have ſpread their veil over the azure plains, the firmament manifeſts to our view it's grandeur and it's riches. The ſparkling points with which it is ſown, are ſo many SUNS ſuſpended by the ALMIGHTY in the immenſity of ſpace, to give light and heat to the worlds which roll around them.

THE HEAVENS DECLARE THE GLORY OF GOD, AND THE FIRMAMENT SHEWETH HIS HANDY WORK. The royal poet, who expreſſed himſelf with ſuch loftineſs of ſentiment, was ignorant that the ſtars he contemplated were in reality ſuns. He anticipated the times, and firſt ſung that majeſtic hymn, which future and more enlightened ages ſhould chaunt forth in praiſe to the FOUNDER OF WORLDS.

The aſſemblage of theſe vaſt bodies is divided into different ſyſtems, the number of which probably ſurpaſſes the grains of ſand which the ſea caſts on it's ſhores.

Each

Each ſyſtem has it's center, or focus, a ſtar, or ſun, which ſhines by it's native inherent light; and round which, ſeveral orders of opake globes revolve, reflecting, with more or leſs brilliancy, the light they borrow from it, and which renders them viſible.

Thoſe globes which we perceive as wandering among the heavenly hoſt, are the PLANETS; the primary, or principal ones, have the ſun for the common center of their periodical revolutions; while the others, which are called ſecondaries, move round their primaries, accompanying them as SATELLITES in their annual revolution.

The earth has one ſatellite, Jupiter four, Saturn five, and the Georgium Sidus two; Saturn has beſides a luminous and beautiful ring.

We know that our ſolar ſyſtem conſiſts of twenty planetary bodies; we are not certain but that there may be more. Their number has been conſiderably augmented ſince the invention of teleſcopes: more perfect inſtruments, and more accurate obſervers, may further increaſe their number; the diſcovery of the Georgium Sidus may be looked upon as the happy preſage of future ſucceſs.

Modern aſtronomy has not only enriched our heavens with new planets, but it has alſo enlarged the boundaries of the ſolar ſyſtem. The comets, which from their fallacious appearance, their tail, their beard, the diverſity of their directions, their

their ſudden appearance and diſappearance, have been conſidered as meteors, lighted up in the air by an irritated power, are found to be a ſpecies of planetary bodies, whoſe long routes are now calculated by aſtronomers; they alſo foretel their diſtant return, determine their place, and account for their irregularities. Many of theſe bodies at preſent acknowledge the empire of our ſun, though the orbits they trace round him are ſo extenſive, that ſeveral ages are neceſſary for the completion of a revolution.

In a word, it is from modern aſtronomy we learn that the ſtars are innumerable, and that the conſtellations, in which the ancients reckoned but a few, are now known to contain thouſands. The heavens of Thales and Hipparchus were very poor when compared to thoſe of Tycho Brahe, Flamſteed, de La Caille, and Herſchel.

The diameter of the great orbit which our earth deſcribes, is more than many millions of leagues; yet this vaſt extent vaniſhes into nothing, and becomes a mere point, when the aſtronomer wiſhes to uſe it as a meaſure, to aſcertain the diſtance of the fixed ſtars.

How great than is the real bulk of theſe luminaries, which are perceptible by us at ſuch an enormous diſtance! the ſun is about 1,392,500 times greater than the earth, and 539½ times greater than all the planets taken together. If the ſtars are ſuns, as we have every

reaſon

reaſon to ſuppoſe, they muſt either be equal to, or exceed it in ſize.

Proud and ignorant mortal! lift up now thine eyes to heaven, and anſwer me: if one of thoſe luminaries which adorn the ſtarry heaven, ſhould be taken away, would thy nights become darker? Say not then, that the ſtars are made for thee; that it is for thee that the firmament glitters with effulgent brightneſs: feeble mortal! thou wert not the chief object of the liberal bounties of the Creator, when he appointed Syrius, and encompaſſed it with worlds.

Whilſt the planets perform their periodical revolutions round the ſun, by which the courſe of their year is regulated, they turn round upon their axes, a motion by which they obtain the alternate ſucceſſion of day and night.

But by what means are theſe vaſt bodies ſuſpended in the immenſity of ſpace? What ſecret power retains them in their orbits, and enables them to circulate with ſo much regularity and harmony? Gravity, or attracton, is the powerful agent, the univerſal principle of this equilibrium, and of theſe motions. It penetrates intimately all bodies. By this power they tend towards each other in a proportion relative to their bulk. Thus the planets tend towards the center of the ſyſtem, into which they would ſoon have been precipitated, if the Creator, when he formed them, had not impreſſed upon them

them a projectile or centrifugal force, which continually keeps them at a proper diſtance from the center.

The planets, by obeying at the ſame inſtant each of theſe motions, are made to deſcribe a curve. This curve is an ellipſe, of different excentricities, according to the combination of the active powers. At one of the foci of this ellipſe the ſun is placed. Thus the ſame force which determines the fall of a ſtone, is the ruling principle of the heavenly motions. Wonderful mechaniſm! whoſe ſimplicity and energy gives us unceaſing tokens of the PROFOUND WISDOM OF IT'S AUTHOR.

The earth, which ſeems ſo vaſt in the eyes of the emmets who inhabit it, and whoſe diameter is above 7970 miles, is yet near a thouſand times ſmaller than Jupiter, who appears to the naked eye as little more than a ſhining atom.

Two troops of academicians, new Argonauts, have had within this century the glory of determining the figure of the earth, and have demonſtrated it to be a ſpheroid, flattened at the poles, elevated at the equator. But Newton has acquired a ſtill greater glory, that of diſcovering, by the powers of genius, the ſame truth previous to obſervation. This figure is alſo the effect of gravity, combined with the centrifugal force. Theſe two powers acting in different proportions, on different planets, vary their figure, and change

them into ſpheroids, more or leſs flat, at the ſame time that they contract or dilate their orbits.

This terraqueous globe is externally divided by land and ſeas. It is internally formed (at leaſt to a certain depth) into beds of heterogeneous matter; the beds are almoſt parallel, but of different denſities and textures.

The ſurface of the earth abounds with irregularities. In one part we find vaſt plains, interſected with hills and vallies. In another, long chains of mountains, which lift their frozen heads to the clouds; from the boſom of theſe mountains proceed rivers, which, after they have watered various countries, and produced ponds and lakes, diſcharge themſelves into the ſea, and reſtore to it what it had loſt by evaporation.

The ſea preſents to our view iſlands ſcattered in all parts of it, ſands, rocks, currents, gulphs, and ſtorms; but above all, that regular and admirable motion whereby it's waters riſe and fall twice every twenty-four hours.

The lands and ſeas are peopled with plants and animals, whoſe infinitely varied ſpecies have each their proper habitation. Mankind divided into nations, people and families, cover the ſurface of the globe. They modify and enrich it by their various labours, and build dwellings from pole to pole, which correſpond with their manners, genius, and climate.

A rare

A rare, tranſparent, and elaſtic ſubſtance ſurrounds the earth to a certain height. This ſubſtance is the atmoſphere, the habitation of the winds, an immenſe reſervoir of vapours, which, when condenſed into clouds, either embelliſh our ſky by the variety of their figures, and the richneſs of their colouring; or aſtoniſh us by the rolling thunder, or flaſhes of lightning, that eſcape from them; ſometimes they melt away, at others are condenſed into rain or hail, ſupplying the deficiencies of the earth with the ſuperfluity of heaven.

The moon, the neareſt of all the planets to the earth, is likewiſe that of which we have the moſt knowledge. It's globe always preſents to us the ſame face, becauſe it turns round upon it's axis preciſely in the ſame ſpace of time that it revolves round the earth.

It has it's phaſes, or gradual and periodical increaſe and decreaſe of light, according to it's poſition with reſpect to the ſun, which enlightens it, and the earth on which it reflects the light that it has received.

The diſk of the moon is divided into luminous and obſcure parts. The former ſeems analogous to land, the latter to reſemble our ſeas.

In the luminous ſpots there have been obſerved ſome parts which are brighter than the reſt, projecting a ſhadow, whoſe length has been meaſured, and track aſcertained. Theſe parts

are mountains, much higher than our's, in proportion to the ſize of the moon, whoſe tops may be ſeen gilded by the rays of the ſun, at the quadratures of the moon, and the light gradually deſcending to their feet, till they appear entirely bright. Some of theſe mountains ſtand by themſelves, while in other places there are long chains of them.

We ſhall not dwell upon the numerous particulars that may be obſerved on an attentive examination of this planet. If the author of nature has with us thought proper to vary the ſmalleſt individual, how great muſt the diverſity be, by which he has diſtinguiſhed one world from another!

Venus has, like the moon, her phaſes, ſpots, and mountains. The teleſcope diſcovers to us alſo ſpots in Mars and Jupiter. Thoſe in Jupiter form belts; conſiderable changes have been ſeen among theſe, as if of the ocean's overflowing the land, and again leaving it dry by it's retreat.

Mercury, Saturn, and the Georgium Sidus, are but little known; the firſt, becauſe he is too near the ſun; the two laſt, becauſe they are ſo remote from it.

Laſtly, the ſun himſelf has ſpots, which ſeem to move with regularity, and whoſe ſize equals, and very often exceeds, our globe itſelf.

Every

Every thing in the univerſe is ſyſtematical, all is combination, affinity, and connection.

The ſpecies and individuals have relation to the ſize of the earth ; the ſize of the earth has it's relation to the place ſhe occupies in the planetary ſyſtem.

The ſun gravitates on the planets; the planets on the ſun and each other. Theſe taken together gravitate on their neighbouring ſyſtems ; theſe again on more diſtant ones ; while the ballance of the univerſe remains in equilibrio, in the hands of the ANCIENT OF DAYS.

From the relations which exiſt between all parts of the world, and by which they conſpire to one general end, reſults the harmony of the world.

The relations which unite all the worlds to one another, conſtitute the harmony of the univerſe.

The beauty of the world is founded in the harmonious diverſity of the beings that compoſe it, in the number, the extent, and the quality of their effects, and in the ſum of happineſs that ariſes therefrom.

E S S A Y II.

BEING

A TREATISE

ON THE

Uſe of the Terreſtrial and Celeſtial Globes.

EXEMPLIFIED IN

A VARIETY OF PROBLEMS,

Arranged in proper Order,

AND INTERSPERSED WITH MUCH CURIOUS BUT RELATIVE INFORMATION.

ESSAY II.

PART I.

A Treatise on the Use of the Terrestrial and Celestial Globes.

Of the Advantages of Globes in general, for illustrating the primary Principles of Astronomy and Geography; and particularly of the Advantages of the Globes, when mounted in my Father's Manner.

UNIVERSAL approbation, the opinion of thoſe that excel in ſcience, and the experience of thoſe that are learning, all concur to prove that the artificial repreſentations of the earth and heavens, on the terreſtrial and celeſtial globes, are the inſtruments the beſt adapted to convey natural and genuine ideas of aſtronomy and geography to young minds.

This ſuperiority they derive principally from their form and figure, which communicates a more juſt idea, and a more adequate repreſenta-

tion

tion of the earth and heavens, than can be formed from any other figure.

To underſtand the nature of the projection of either ſphere in plano, requires more knowledge of geometry than is generally poſſeſſed by beginners, it's principles are more recluſe, and the ſolution of problems more obſcure.

The motion of the earth upon it's axis is one of the moſt important principles both in geography and aſtronomy; on it the greater part of the phænomena of the viſible world depend: but there is no invention that can communicate ſo natural a repreſentation of this motion, as that of a terreſtrial globe about it's axis. By a celeſtial globe, the apparent motion of the heavens is alſo repreſented in a natural and ſatisfactory manner.

In order to convey a clear idea of the various diviſions of the earth, of the ſituation of different places, and to obtain an eaſy ſolution of the various problems in geography, it is neceſſary to conceive many imaginary circles delineated on it's ſurface, and to underſtand their relation to each other. Now on a globe theſe circles have their true form; their interſections and relative poſitions are viſible upon the moſt curſory inſpection. But in projections of the ſphere in plano, the form of theſe circles is varied, and their nature changed; they are conſequently but ill adapted to convey to young minds

minds the elementary principles of geography.

On a globe, the appearance of the land and water is perfectly natural and continuous, fitted to convey accurate ideas, and leave permanent impressions on the most tender minds; whereas, in planispheres one-half of the globe is separated and disjoined from the other; and those parts which are contiguous on a globe, are here separated and thrown at a distance from each other. The celestial globe has the same superiority over projections of the heavens in plano.

The globe exhibits every thing in true proportion, both of figure and size; while on a planisphere the reverse may often be observed.

Presuming that these reasons sufficiently evince the great advantage of globes over either planispheres or maps, for obtaining the first principles of astronomical and geographical knowledge, I proceed to point out the pre-eminence of globes mounted in my father's manner, over the common, or rather the old and Ptolemaic mode of fitting them up.

The great and increasing sale of his globes mounted in the best manner may be looked upon at least as a proof of approbation from numbers; to this I might also add, the encouragement they have received from the principal tutors of both our universities, the public sanction of the university of Leyden, the many editions of my father's

father's treatiſe on their uſe, and it's tranſlation into Dutch, &c. The recommendation of Meſſ. Arden, Walker, Burton, &c. public lecturers in natural philoſophy, might alſo be adduced; but leaving theſe conſiderations, I ſhall proceed to enumerate the reaſons which give them, in my opinion, a decided preference over every other kind of mounting.*

The

* The following note from Mr. Walker's Eaſy Introduction to Geography, in favor of my father's globes, will not, I hope, be deemed improper.

"Simplicity and perſpicuity ſhould ever be ſtudied by thoſe who cultivate the young mind; and jarring, oppoſing, or equivocal ideas ſhould be avoided almoſt as much as error or falſehood. Our globes, till of late years, were equipt with an hour circle, which prevented the poles from ſliding through the horizon; hence their rectification was generally for the PLACE ON THE EARTH, inſtead of the SUN'S PLACE IN THE ECLIPTIC; which put the globe into ſo unnatural and abſurd a poſition reſpecting the ſun, that young people were confounded when they compared it with the earth's poſitions during it's annual rotation round that luminary, and conſidering the horizon as the boundary of day and night. Being, therefore, ſometimes obliged to rectify for the place on the earth, and ſometimes for the ſun's place in the ecliptic, the two rules claſh ſo unhappily in the pupil's mind, that few remember a ſingle problem a twelvemonth after the end of their tuition. Globes, therefore, with the horary circle, are but partially deſcribed in this treatiſe; the great intention of which is, to make the elevations and depreſſions of the

poles

The earth, by it's diurnal revolution on it's axis, is carried round from weſt to eaſt. To repreſent this real motion of the earth, and to ſolve problems agreeable thereto, it is neceſſary that the globe, in the ſolution of every problem, ſhould be moved from WEST TO EAST; and for this purpoſe, that the diviſions on the large braſs circle ſhould be on that ſide which looks weſtward.* Now this is the caſe in my father's mode of mounting the globes, and the tutor can thereby explain with eaſe the rationale of any problem to his pupil. But in the common mode of mounting, the globe muſt be moved from eaſt to weſt, according to the Ptolemaic ſyſtem; and conſequently, if the tutor endeavours to ſhew how things obtain in nature, he muſt make his pupil unlearn in a degree what he has taught him, and by abſtraction reverſe the method he has inſtructed

poles of a terreſtrial globe to repreſent ALL the ſituations the earth is in to the ſun, for every day or hour through the year. The globes of Mr. ADAMS are the moſt favourable for the above mode of rectification of any plates we have at preſent; and to make a quieſcent globe to repreſent all the poſitions of one revolving round the ſun, turning on an inclined axis, and keeping that axis altogether parallel to itſelf, his globes are better adapted than any, I believe, in being."

* See the Rev. Mr. Hutchins's New Treatiſe on the Globes, p. 3; Adams's Treatiſe on the Globes.

ſtructed him to uſe; a practice that we hope will not be adopted by many.

The celeſtial globe being intended to repreſent the apparent motion of the heavens, ſhould be moved, when uſed, from eaſt to weſt.

Of the phænomena to be explained by the terreſtrial globe, the moſt material are thoſe which relate to the changes in the ſeaſons; all the problems connected with, or depending upon theſe phænomena, are explained in a clear, familiar, and natural manner, by the globe, when mounted in my father's mode; for on rectifying it for any particular day of the month, it immediately exhibits to the pupil the exact ſituation of the globe of the earth for that day; and while he is ſolving his problem, the reaſon and foundation of it preſents itſelf to the eye and underſtanding.

The globe may alſo be placed with eaſe in the poſition of a right ſphere, a circumſtance exceedingly uſeful, and which the old conſtruction of the globes did not admit of.

By the application of a moveable meridian, and an artificial horizon connected with it, it is eaſy to explain why the ſun, although he be always in one and the ſame place, appears to the inhabitants of the earth at different altitudes, and in different azimuths, which cannot be ſo readily done with the common globes.

On

On the celeſtial globe there is a moveable circle of declination, with an artificial ſun.

The braſs wires placed under the globes, ſerve to diſtinguiſh, in a natural and ſatisfactory manner, twilight from total darkneſs, and the reaſon of the length of it's duration.

The next point wherein they materially differ from other globes, is in the hour circle. Now it muſt be confeſſed, that to every contrivance that has been uſed for this purpoſe there is ſome objection, and probably no mode can be hit upon that will be perfectly free from them. The method adopted by my father appears to me the leaſt exceptionable, and to poſſeſs ſome advantages over every other method I am acquainted with. Agreeable to the opinion of the firſt aſtronomers, among others of M. de la Lande, he uſes the equator for the hour circle, not only as the largeſt, but alſo as the moſt natural circle that could be employed for that purpoſe, and by which alone the ſolution of problems could be obtained with the greateſt accuracy. As on the terreſtrial globe, the longitude of different places is reckoned on this circle; and on the celeſtial, the right aſcenſion of the ſtars, &c. it familiarizes the young pupil with them, and their reduction to time. This method does not in the leaſt impede the motion of the globe; but while it affords an equal facility of elevating either the north or ſouth pole, it prevents the pupil from placing

them in a wrong poſition; while the horary wire ſecures the globe from falling out of the frame.

Another circumſtance peculiar to theſe globes, is the mode of fixing the compaſs. It is ſelf-evident, that the tutor, who is willing to give correct ideas to his pupil, ſhould always make him keep the globes with the north pole directed towards the north pole of the heavens, and that, both in the ſolution of problems, and the explanation of phænomena. By means of the compaſs, the terreſtrial globe is made to ſupply the purpoſe of a tellurian, when ſuch an inſtrument is not at hand. I cannot terminate this paragraph, without teſtifying my diſapprobation of a mode adopted by ſome, of making the globe turn round upon a pin in the pillar on which it is ſupported: a mode, that while it can give but little relief to indolence, is leſs firm in it's conſtruction, and tends to introduce much confuſion in the mind of the pupil.

In order to prevent that confuſion and perplexity which neceſſarily ariſes in a young mind, when names are made uſe of which do not properly characterize the ſubject, my father found it neceſſary, with Mr. Hutchins, to term that broad wooden circle which ſupports the globe, and on which the ſigns of the ecliptic and the days of the month are engra-

engraved, the BROAD PAPER CIRCLE, inſtead of horizon, by which it had been heretofore denominated. The propriety of this change will be evident to all thoſe who conſider that this circle in ſome caſes repreſents that which divides light from darkneſs, in others the horizon, and ſometimes the ecliptic. For ſimilar reaſons, he was induced to call the brazen circle, in which the globes are ſuſpended, the STRONG BRASS CIRCLE.

In a word, many operations may be performed by theſe globes, which cannot be ſolved by thoſe mounted in the common manner; while all that they can ſolve may be performed by theſe, and that with a greater degree of perſpicuity; and many problems may be performed by theſe at one view, which on the other globes require ſucceſſive operations.

But as notwithſtanding their ſuperiority, the difference in price may make ſome perſons prefer the old conſtruction, it may be proper to inform them, that they may have my father's, or Senex's globes mounted in the old manner, at the uſual prices.

ESSAY II.

PART II.

CONTAINING A DESCRIPTION OF THE GLOBES MOUNTED IN THE BEST MANNER; TOGETHER WITH SOME PRELIMINARY DEFINITIONS.

DEFINITIONS.

BEFORE we begin to defcribe the globes, it will be proper to take fome notice of the properties of a circle, of which a globe may be faid to be conftituted.

A LINE is generated by the motion of a point.

Let there be fuppofed two points, the one moveable, the other fixed.

If the moveable point be made to move directly towards the fixed point, it will generate in it's motion a ftrait line.

If a moveable point be carried round a fixed point, keeping always the fame diftance from it, it will generate a CIRCLE, or fome part of a circle, and

and the fixed point will be the CENTER of that circle.

All ftrait lines going from the center to the circumference of a circle, are equal.

Every ftrait line that paffes through the center of a globe, and is terminated at both ends by it's furface, is called a DIAMETER.

The extremities of a diameter are it's poles.

If the circumference of a femicircle be turned round it's diameter, as on an axis, it will generate a globe, or fphere.

The center of the femicircle will be the center of the globe; and as all points of the generating femicircle are at an equal diftance from it's center, fo all the points of the furface of the generated fphere are at an equal diftance from it's center.

Description of the Globes.

There are two artificial globes; on the furface of one of them the heavens are delineated, this is called the CELESTIAL GLOBE. The other, on which the furface of the earth is defcribed, is called the TERRESTRIAL GLOBE.

Fig. 2, plate XIV. reprefents the celeftial; fig. 1, plate XIV. the terreftrial globe, as mounted in my father's manner.

In ufing the celeftial globe, we are to confider ourfelves as at the CENTER.

In uſing the terreſtrial globe, we are to ſuppoſe ourſelves on ſome point of it's SURFACE.

The motion of the terreſtrial globe repreſents the REAL motion of the earth.

The motion of the celeſtial globe repreſents the APPARENT motion of the heavens.

The motion therefore of the celeſtial globe is a motion from EAST TO WEST.

But the motion of the terreſtrial globe is a motion from WEST TO EAST.

On the ſurface of each globe ſeveral circles are deſcribed, to every one of which may be applied what has been ſaid of circles in page 243.

The center of ſome of theſe circles is the ſame with the center of the globe; theſe are, by way of diſtinction, called GREAT CIRCLES.

Of theſe great circles, ſome are graduated.

The graduated circles are divided into 360°, or equal parts, 90 of which make a quarter of a circle, or a quadrant.

Thoſe circles whoſe centers do not paſs through the center of the globe, are called LESSER CIRCLES.

The globes are each of them ſuſpended at the poles in a ſtrong braſs circle N Z Æ S, and turn therein upon two iron pins, which are the axis of the globe; they have each a thin braſs ſemicircle N H S, moveable about theſe poles, with a ſmall thin circle H ſliding thereon; it is quadra-

ted

ted each way to 90° from the equator to either pole.

On the terreſtrial globe this ſemicircle is a MOVEABLE MERIDIAN. It's ſmall ſliding circle, which is divided into a few of the points of the mariner's compaſs, is called a TERRESTRIAL OR VISIBLE HORIZON.

On the celeſtial globe, this ſemicircle is a MOVEABLE CIRCLE OF DECLINATION, and it's ſmall braſs circle an artificial ſun, or planet.

Each globe has a braſs wire circle T W Y, placed at the limits of the crepuſculum, or twilight, which, together with the globe, is mounted in a wooden frame; the upper part B C is covered with a broad paper circle, whoſe plane divides the globe into two hemiſpheres, and the whole is ſupported by a neat pillar and claw, with a magnetic needle in a compaſs box marked M.

A DESCRIPTION OF THE CIRCLES DESCRIBED ON THE BROAD PAPER CIRCLE B C; TOGETHER WITH A GENERAL ACCOUNT OF IT'S USES.

It contains four concentric circular ſpaces, the innermoſt of which is divided into 360°, and numbered into four quadrants, beginning at the eaſt and weſt points, and proceeding each way to 90°, at the north and ſouth points; theſe are the four cardinal points of the horizon.

The ſecond circular ſpace contains, at equal diſtances, the thirty-two points of the mariner's compaſs. Another circular ſpace is divided into twelve equal parts, repreſenting the twelve ſigns of the zodiac; theſe are again ſubdivided into 30 degrees each, between which are engraved their names and characters. This ſpace is connected with a fourth; which contains the calendar of months and days, each day on the 18 inch globes being divided into four parts, expreſſing the four cardinal points of the day, according to the Julian reckoning; by which means, the ſun's place is very nearly obtained for the common years after biſſextile, and the intercalary day is inſerted without confuſion.

In all poſitions of the celeſtial globe, this broad paper circle repreſents the plane of the horizon, and diſtinguiſhes the viſible from the inviſible part of the heavens; BUT IN THE TERRESTRIAL GLOBE IT IS APPLIED TO THREE DIFFERENT USES.

1. To diſtinguiſh the points of the horizon; in this caſe it repreſents the rational horizon of any place.

2. It is uſed to repreſent the circle of illumination, or that circle which ſeparates day from night.

3. It occaſionally repreſents the ecliptic.

Of

Of the strong Brass Circle N Æ Z S.

One ſide of this ſtrong braſs circle is graduated into four quadrants, each containing 90 degrees.

The numbers on two of theſe quadrants increaſe from the equator towards the poles ; the other two increaſe from the pole towards the equator.

Two of the quadrants are numbered from the equator, to ſhew the diſtance of any point on the globe from the equator. The other two are numbered from the poles, for the more ready ſetting the globe to the latitude of any place.

The ſtrong braſs circle of the celeſtial globe is called the meridian, becauſe the center of the ſun comes directly under it at noon.

But as there are other circles on the terreſtrial globe, which are called meridians, we chuſe to denominate this the STRONG BRASS CIRCLE, or MERIDIAN.

The graduated ſide of the ſtrong braſs circle that belongs to the terreſtrial globe, ſhould face the WEST.

The graduated ſide of the ſtrong brazen meridian of the celeſtial globe ſhould face the EAST.

On the ſtrong braſs circle of the terreſtrial globe, and at about 23½ degrees on each ſide of the north pole, the days of each month are laid down according to the declination of the ſun.

OF THE HORARY CIRCLES, AND THEIR INDICES.

When the globes are mounted in my father's manner, we uſe the equator as the hour circle; becauſe it is not only the moſt natural, but alſo the largeſt circle that can be applied for that purpoſe.

To make this circle anſwer the purpoſe, a ſemicircular wire is placed over it, carrying two indices, one on the eaſt, the other on the weſt ſide of the ſtrong braſs circle.

As the equator is divided into 360°, or 24 hours, the time of one entire revolution of the earth or heavens, the indices will ſhew in what ſpace of time any part of ſuch revolution is made among the hours which are graduated below the degrees of the equator on either globe.

As the motion of the terreſtrial globe is from weſt to eaſt, the horary numbers increaſe according to the direction of that motion; on the celeſtial globe they increaſe from the eaſt to the weſt.

OF THE QUADRANT OF ALTITUDE, Z A.

It is a thin, narrow, flexible ſlip of braſs, that will bend to the ſurface of the globe; it has a nut, with a fiducial line upon it, which may be readily applied to the diviſions on the ſtrong braſs meridian of either globe. One edge of the quadrant is

is divided into 90 degrees, and the divifions are continued to 18 degrees below the horizon.

Of some of the Circles that are described upon the Surface of each Globe.

We may fuppofe as many circles to be defcribed on the furface of the earth as we pleafe, and conceive them to be extended to the fphere of the heavens, marking thereon concentric circles. For as we are obliged, in order to diftinguifh one place from another, to appropriate names to them, fo are we obliged to ufe different circles on the globes, to diftinguifh the parts, and their feveral relations to each other.

Of the Equator, or Equinoctial.

It goes round the globe exactly in the middle, between the two poles, from which it always keeps at the fame diftance; or in other words, it is every where 90 degrees diftant from each pole, and is therefore a boundary, feparating the northern from the fouthern hemifphere; hence it is frequently called THE LINE by failors, and when they fail over it they are faid to crofs the line.

It is that circle in the heavens, in which the fun appears to move on thofe two days, the one in the fpring, the other in the autumn, when the days and nights are of an equal length all over the

the world; and hence on the celeſtial globe it is generally called the EQUINOCTIAL.

It is graduated into 360 degrees. Upon the terreſtrial globe the numbers increaſe from the meridian of London weſtward, and proceed quite round to 360. They are alſo numbered from the ſame meridian eaſtward, by an upper row of figures, to accommodate thoſe who uſe the Engliſh tables of latitude and longitude.

On the celeſtial globe, the equatorial degrees are numbered from the firſt point of Aries eaſtward, to 360 degrees.

Under the degrees on either globe is graduated a circle of hours and minutes. On the celeſtial globe the hours increaſe eaſtward, from Aries to XII at Libra, where they begin again in the ſame direction, and proceed to XII at Aries. But on the terreſtrial globe, the horary numbers increaſe by twice twelve hours weſtward from the meridian of London to the ſame again.

In turning the globe about, the equator keeps always under one point of the ſtrong braſs meridian, from which point the degrees on the ſaid circle are numbered both ways.

OF THE ECLIPTIC.

The graduated circle, which croſſes the equator obliquely, forming with it an angle of about $23\frac{1}{2}$ degrees, is called the ecliptic.

This

This circle is divided into 12 equal parts, each of which contains 30 degrees. The beginning of each of theſe 30 degrees is marked with the characters of the 12 ſigns of the zodiac.

The ſun appears always in this circle; he advances therein every day, nearly a degree, and goes through it exactly in a year.

The points where this circle croſſes the equator are called the EQUINOCTIAL POINTS. The one is at the beginning of Aries, the other at the beginning of Libra.

The commencement of Cancer and Capricorn are called the SOLSTITIAL POINTS.

The twelve ſigns, and their degrees, are laid down on the terreſtrial globe; but upon the celeſtial globe, the days of each month are graduated juſt under the ecliptic.

The ecliptic belongs principally to the celeſtial globe.

ESSAY

ESSAY II.

PART III.

THE USE OF THE TERRESTRIAL GLOBE, MOUNTED IN THE BEST MANNER.

OF LONGITUDE AND LATITUDE, AND OF TERRESTRIAL MERIDIANS.

MERIDIANS are circular lines, going over the earth's ſurface, from one pole to the other, and croſſing the equator at right angles.

Whatever places theſe circular lines paſs through, in going from pole to pole, they are the meridians of thoſe places.

There are no places upon the ſurface of the earth, through which meridians may not be conceived to paſs. Every place, therefore, is ſuppoſed to have a meridian line paſſing over it's zenith from north to ſouth, and going through the poles of the world.

Thus the meridian of Paris is one meridian; the meridian of London is another. This variety of meridians is ſatisfactorily repreſented

on

on the globe, by the moveable meridian, which may be fet to every individual point of the equator, and put directly over any particular place.

Whenfoever we move towards the eaft or weft, we change our meridian; but we do not change our meridian if we move directly to the north or fouth.

The moveable meridian fhews that the poles of the earth divide every meridian into two femicircles, one of which paffes through the place whofe meridian it is, the other through a point on the earth, oppofite to that place.

Hence it is, that writers in geography and aftronomy generally mean by the MERIDIAN of any place the SEMICIRCLE which paffes through that place; thefe, therefore, may be called the geographical meridians.

All places lying under the fame femicircle, are faid to have the fame meridian; and the femicircle oppofite to it is called the oppofite meridian, or fometimes the oppofite part of the meridian.

From the foregoing definitions, it is clear that the meridian of any place is immoveably fixed to that place, and is carried round along with it by the rotation of the globe.

When the meridian of any place is by the revolution of the earth brought to point at the fun, it is noon, or mid-day, at that place.

The

The plane of the meridian of any place may be imagined to be extended to the ſphere of the fixed ſtars.

When, by the motion of the earth, the plane of a meridian comes to any point in the heavens, as the ſun, moon, &c. that point, &c. is then ſaid to come to the meridian. It is in this ſenſe that we generally uſe the expreſſion of the ſun or ſtars coming to, or paſſing over the meridian.

The time which elapſes between the noon of any one day in a given place, and the noon of the day following in the ſame place, is called A NATURAL DAY.

All places which lie under the ſame meridian, have their noon, and every other hour of the natural day, at the ſame time. Thus when it is one in the afternoon at London, it is alſo one in the afternoon to every place under the meridian of London.

In order to aſcertain the ſituation of any point, there muſt firſt be a ſettled part of the earth's ſurface, from which to meaſure; and as the point to be aſcertained may lie in any part of the earth's ſurface, and as this ſurface is ſpherical, the place from whence we meaſure muſt be a circle. It would be neceſſary, however, to eſtabliſh two ſuch circles, one to know how far any place may be eaſt or weſt of another, the ſecond to know it's diſtance north or ſouth

fouth of the given point, and thus determine it's precife fituation.

Hence it has been cuftomary for geographers to fix upon the meridian of fome remarkable place, AS A FIRST MERIDIAN, OR STANDARD; and to reckon the diftance of any place to the eaft or weft, or it's longitude, by it's diftance from the firft meridian. On Englifh globes, this firft meridian is made to pafs through London. The pofition of this firft meridian is arbitrary, becaufe on a globe, properly fpeaking, there is neither beginning nor end. The firft perfon (whofe works at leaft are come down to us) who computed the diftance of places by longitudes and latitudes was Ptolemy, about the year after Chrift, 140.

The LONGITUDE OF ANY PLACE is it's diftance from the firft meridian, meafured by degrees on the equator.

To find the longitude of a place, is to find what degree on the equator the meridian of that place croffes.

All places that lie under the fame meridian, are faid to have the fame longitude; all places that lie under different meridians, are faid to have different longitudes; this difference may be eaft or weft, and confequently the difference of longitude between any two places, is the diftance of their meridians from each other meafured on the equator.

4

Thus

Thus if the meridian of any place cuts the equator in a point, which is fifteen degrees eaſt from that point, where the meridian of London cuts the equator, that place is ſaid to differ from London in longitude 15 degrees eaſtward.

Upon the terreſtrial globe there are 24 meridians, dividing the equator into 24 equal parts, which are the hour circles of the places through which they paſs.

The diſtance of theſe meridians from each other is 15 degrees, or the 24th part of 360 degrees; thus 15 degrees is equal to one hour.

By the rotation of the earth, the plane of every meridian points at the ſun, one hour after that meridian which is next to it eaſtward; and thus they ſucceſſively point at the ſun every hour, ſo that the plane of the 24 meridian ſemicircles being extended, paſs through the ſun in a natural day.

To illuſtrate this, ſuppoſe the plane of the ſtrong braſs meridian to coincide with the ſun, bring London to this meridian, and then move the globe round, and you will find theſe 24 meridians ſucceſſively paſs under the ſtrong braſs meridian, at one hour's diſtance from each other; till in 24 hours the earth will return to the ſame ſituation, and the meridian of London will again coincide with the ſtrong braſs circle.

By paſſing the globe round, as in the foregoing article, it will be evident to the pupil, that if one

of

of theſe meridians, 15 degrees eaſt of London, comes to the ſtrong braſs meridian, or points at the ſun one hour ſooner than the meridian of London, a meridian that is 30 degrees eaſt comes two hours ſooner, and ſo on; and conſequently they will have noon, and every other hour, ſo much ſooner than at London: while thoſe, whoſe meridian is 15 degrees weſtward from London, will have noon, and every other hour of the day, one hour later than at London, and ſo on, in proportion to the difference of longitude. Theſe definitions being well underſtood, the pupil will be prepared not only to ſolve, but ſee the rationale of the following problems.

PROBLEM I.

To find the longitude of any place on the globe.

The reader will find no difficulty in ſolving this problem, if he recollects the definition we have given of the word longitude, namely, that it is the diſtance of any place from the firſt meridian meaſured on the equator. Therefore, either ſet the moveable meridian to the place, or bring the place under the ſtrong braſs meridian, and that degree of the equator, which is cut by either of theſe brazen meridians, is the longitude in degrees and minutes, or the hour and minute of it's longitude, expreſſed in time.

As the given place may lie either eaſt or weſt

of the firſt meridian, the longitude may be expreſſed accordingly.

It appears moſt natural to reckon the longitude always weſtward from the firſt meridian; but it is cuſtomary to reckon one half round the globe eaſtward, and the other half weſtward from the firſt meridian. To accommodate thoſe who may prefer either of theſe plans, there are two ſets of numbers on our globes: the numbers neareſt the equator increaſe weſtward, from the meridian of London quite round the globe to 360°, over which another ſet of numbers is engraved, which increaſe the contrary way; ſo that the longitude may be reckoned upon the equator, either eaſt or weſt.

Example. Bring Boſton, in New England, to the graduated edge of either the ſtrong braſs, or of the moveable meridian, and you will find it's longitude in degrees to be 70½, or 4 h. 42 min. in time; Rome 12½ degrees eaſt, or 50 min. in time; Charles-Town, North America, is 79 deg. 50 min. weſt.

PROBLEM II.

To find the difference of longitude between any two places.

If the pupil underſtands what is meant by the difference of longitude, the rule for the ſolution of this problem will naturally occur to his mind.

 Now

Now the difference of longitude between any two places is the quantity of an angle (at the pole) made by the meridians of thoſe places meaſured on the equator. To expreſs this angle upon the globe, bring the moveable meridian to one of the places, and the other place under the ſtrong braſs circle, and the required angle is contained between theſe two meridians, the meaſure or quantity of which is to be counted on the equator.

Example. I find the longitude of Rome to be 12½ eaſt, that of Conſtantinople to be 29, the difference is 17½ degrees. Again, I find Jeruſalem has 35 deg. 25 min. eaſt longitude from London; and Pekin, in China, 116 deg. 52 min. eaſt longitude; the difference is 81 deg. 27 min.; that is, Pekin is 81 deg. 27 min. eaſt longitude from Jeruſalem; or Jeruſalem is 81 deg. 27 min. weſt longitude from Pekin.

If one place is eaſt, and the other weſt of the firſt meridian, either find the longitude of both places weſtward, by that ſet of numbers which increaſe weſtward from the meridian of London to 360 deg. and the difference between the number thus found is the anſwer to the queſtion:—or, add the eaſt and weſt longitudes, and the ſum is the difference of longitude; thus the longitude of Rome is 12 deg. 30 min. eaſt, of Charles-Town 79 deg. 50 min. weſt; their ſum, 91 deg. 20 min. is the difference required.

It may be proper to obſerve here, that the difference in time is the ſame with the difference of longitude, conſequently that ſome of the following problems are only particular caſes of this problem, or readier modes of computing this difference.

PROBLEM III.

To find all thoſe places where it is noon, at any given hour of the day, in another place; or in other words, (which may conduct the reader to the rationale of it's ſolution) to find what places have the ſun upon their meridian, at any given hour of the day, in another propoſed place.

As the diurnal motion of the earth, here repreſented by the terreſtrial globe, is from weſt to eaſt, it is plain that all places which are to the eaſt of any particular meridian, muſt neceſſarily paſs by the ſun, before a meridian which is to the weſt of them can arrive at it.

We ſhall, therefore, divide this problem into three caſes.

1. When the given hour is at London.

2. When the given hour is in the morning, and any where but at London.

3. When the given hour is in the afternoon, but not at London.

1. When

1. When the given hour is at London.

As the firſt meridian on our globes paſſes through London, bring the given hour to the eaſt of London, if it be in the morning, to the ſtrong braſs meridian, and all thoſe places which are under it will have noon at the given hour; but bring the given hour weſt of London, if it be in the afternoon.

Example. Let it be required to know in what places it is XII o'clock, when it is ten in the morning at London. Therefore, bring that Xth hour on the equator, which is to the eaſtward of London, under the ſtrong braſs meridian, and the places that are under it's graduated edge will have the ſun upon their meridian when it is ten in the morning at London. Suppoſe the given hour at London to be three o'clock, then bring that hour on the equator which is weſtward of London, to the ſtrong braſs meridian, and thoſe places which lie under it will have noon when it is three in the afternoon at London.

2. If the given hour be in the afternoon, but not at London.

Bring the given place to the ſtrong braſs meridian, and ſet one of the hour indexes to that XII which is moſt elevated; then turn the globe from west to east, till the index points

to the given hour, and the ſtrong braſs meridian will paſs over thoſe places which have noon at the given hour in the propoſed place.

Let the hour propoſed be IV o'clock in the afternoon, at Port-Royal, in Jamaica. Bring Port-Royal to the ſtrong braſs meridian, and ſet the hour index to the moſt elevated XII; turn the globe from weſt to eaſt, until the horary index points to IV o'clock, and the ſtrong braſs meridian will paſs over thoſe places which have noon at the given hour in Jamaica.

3. IF THE GIVEN HOUR BE IN THE MORNING, BUT NOT AT LONDON.

Bring the given place to the ſtrong braſs meridian; ſet the hour index to the uppermoſt XII, and turn the globe from EAST to WEST, until the hour index points to the given hour; then the required places are under the ſtrong braſs meridian. Let the given hour be 30 min. paſt V at Cape Paſaro, in the iſland of Sicily: bring Paſaro to the meridian, ſet the hour index to the moſt elevated XII, then move the globe weſtward, till the hour index points to 30 min. paſt V, and the places under the ſtrong braſs meridian will have noon when it is 30 min. paſt V in the afternoon at Paſaro, in Sicily.

PROBLEM

PROBLEM IV.

When it is noon at any place, to find what hour of the day it is at any other place.

Rule. Bring the place at which it is noon, to the ſtrong braſs meridian, and ſet the hour index to the uppermoſt XII, and then turn the globe about till the other place comes under the ſtrong braſs meridian, and the hour index will ſhew upon the equator the required hour.

If to the eaſtward of the place where it is noon, the hour found will be in the afternoon; if to the weſtward, it will be in the forenoon.

Thus when it is noon at London, it is 50 min. paſt XII at Rome; 32 min. paſt VII in the evening at Canton, in China; 15 min. paſt VII in the morning at Quebec, in Canada.

PROBLEM V.

At any given hour in the place where you are, to find the hour at any place propoſed; or in other words, the hour where you are being given, to tell what hour it is in any other part of the world.

Rule. Bring the propoſed place under the ſtrong braſs meridian, ſet the hour index to the given time, then turn the globe, till the place where you are is under the braſs meridian, and the horary index will point to the hour required.

Thus ſuppoſe we are at London at IX o'clock

in the morning, what is the time at Canton, in China? Anſwer, 31 min. paſt IV in the afternoon. When it is IX in the evening at London, it is about 15 min. paſt IV in the afternoon at Quebec, in Canada.

Of Latitude.

We have already obſerved, that the equator divides the globe into two hemiſpheres, the northern and the ſouthern.

The latitude of a place is it's diſtance from the equator towards the north or ſouth pole, meaſured by degrees upon the meridian of the place.

All places, therefore, that lie under the equator, are ſaid to have NO LATITUDE.

All other places upon the earth are ſaid to be in north or ſouth latitude, as they are ſituated on the north or ſouth ſide of the equator; and the latitude of any place will be greater or leſs, according as it is further from, or nearer to the equator.

Lines which keep always at the ſame diſtance from each other, are called PARALLELS.

If a circle, or circular line, be conceived keeping at the ſame diſtance from the equator, it will be a parallel to the equator.

Circles of this kind are commonly drawn on the terreſtrial globe, on both ſides of the equator.

A circle of this kind at 10 degrees from the equator, is called a parallel of 10 degrees.

When

When any ſuch parallel paſſes through two places on the globe's ſurface, thoſe two places have the ſame latitude.

Hence parallels to the equator are called PARALLELS OF LATITUDE.

There are four principal leſſer circles parallel to the equator, which divide the globe into five unequal parts, called ZONES.

The circle on the north ſide of the equator is called the TROPIC OF CANCER; it juſt touches the north part of the ecliptic, and ſhews the path the ſun appears to deſcribe, the longeſt day in ſummer.

That which is on the ſouth ſide of the equator, is called the TROPIC OF CAPRICORN; it juſt touches the ſouth part of the ecliptic, and ſhews the path the ſun appears to deſcribe, the ſhorteſt day in winter.

The ſpace between theſe two tropics, which contains about 47 degrees, was called by the ancients, the TORRID ZONE.

The two polar circles are placed at the ſame diſtance from the poles, that the two tropics are from the equator.

One of theſe is called the NORTHERN, the other the SOUTHERN POLAR CIRCLE.

Theſe include $23\frac{1}{2}$ degrees on each ſide of their reſpective poles, and conſequently contain 47 degrees, equal to the number of degrees included between the tropics.

The

The ſpace contained within the northern polar circle, was by the ancients called the NORTH FRIGID ZONE; and that within the ſouthern polar circle, the SOUTH FRIGID ZONE.

The ſpaces between either polar circle, and it's neareſt tropic, which contain about 43 degrees each, were called by the ancients the TWO TEMPERATE ZONES.

PROBLEM VI.

To find the latitude of any place.

If the pupil comprehends the foregoing definition, he will find no difficulty in the ſolution of this and ſome of the following problems.

Rule. Bring the place to the graduated ſide of the ſtrong braſs meridian, and the degree which is over it is the latitude. Thus London will be found to have 51 deg. 32 min. north latitude; Conſtantinople 41 deg. north latitude; and the Cape of Good Hope 34 deg. ſouth latitude.

PROBLEM VII.

To find all thoſe places which have the ſame latitude with any given place.

Suppoſe the given place to be London; turn the globe round, and all thoſe places which paſs under the ſame point of the ſtrong braſs meridian, are in the ſame latitude.

PROBLEM

PROBLEM VIII.

To find the difference of latitude between two places.

Rule. If the places be in the ſame hemiſphere, bring each of them to the meridian, and ſubtract the latitude of one from the other. If they are in different hemiſpheres, add the latitude of one to that of the other.

Example. The latitude of London is 51 deg. 32 min.; that of Conſtantinople 41 deg.; their difference is 10 deg. 32 min. Of the difference between London, 51 deg. 32 min. north, and the Cape of Good Hope, 34 deg. ſouth, is 84 deg. 32 min.

PROBLEM IX.

The latitude and longitude of any place being known, to find that place upon the globe; or if the place be not inſerted on the globe, to find where it ought to be placed, and fix the center of the artificial horizon thereto.

Rule. Seek for the given longitude in the equator, and bring the moveable meridian to that point; then count from the equator on the meridian, the degree of latitude either towards the north or ſouth pole, and bring the artificial horizon to that degree, and the interſection of it's edge with the meridian, is the ſituation required.

Example.

Example. The latitude of Smyrna, in Afia, is 38 deg. 28 min. north; it's longitude 27 deg. 30 min. eaft of London; therefore, bring 27 deg. 30 min. counted eaftward on the equator, to the moveable meridian, and flide the diameter of the artificial horizon to 38 deg. 28 min. north latitude, and it's center will be correctly placed over Smyrna.

It may be proper in this place juft to fhew the pupil, that THE LATITUDE OF ANY PLACE IS ALWAYS EQUAL TO THE ELEVATION OF THE POLE OF THE SAME PLACE ABOVE THE HORIZON. The reafon of this is, that from the equator to the pole is 90 degrees, from the zenith to the horizon is alfo 90 degrees; the diftance of the zenith to the pole is common to both, and therefore if taken away from both, muft leave equal remains; that is, the diftance from the equator to the zenith, which is the latitude, is equal to the elevation of the pole.

As the finding the longitude of places forms one of the moft important problems in geography and aftronomy, fome further account of it, it is prefumed, will prove entertaining and ufeful to the reader.

" For what can be more interefting to a perfon in a long voyage, than to be able to tell upon what part of the globe he is, to know how far he has travelled, what diftance he has to go, and how he muft direct his courfe to arrive at

the place he deſigns to viſit? Theſe important particulars are all determined by knowing the latitude and longitude of the place under conſideration. When the diſcovery of the compaſs invited the voyager to quite his native ſhore, and venture himſelf upon an unknown ocean, that knowledge which before he deemed of no importance, now became a matter of abſolute neceſſity. Floating in a frail veſſel, upon an uncertain abyſs, he has conſigned himſelf to the mercy of the winds and waves, and knows not where he is."*

The following inſtance will prove of what uſe it is to know the longitude of places at ſea. The editor of Lord Anſon's voyage, ſpeaking of the iſland of Juan Fernandez, adds, "The uncertainty we were in of it's poſition, and our ſtanding in for the main on the 28th of May, in order to ſecure a ſufficient caſting, when we were indeed extremely near it, coſt us the lives of between 70 and 80 of our men, by our longer continuance at ſea; from which fatal accident we might have been exempted, had we been furniſhed with ſuch an account of it's ſituation, as we could fully have depended on."

The latitude of a place the ſailor can eaſily diſcover; but the longitude is a ſubject of the utmoſt

* Bonnycaſtle's Aſtronomy.

utmoſt difficulty, for the diſcovery of which many methods have been deviſed. It is indeed of ſo great conſequence, that the parliament of Great Britain propoſed a reward of 10,000 *l.* if it extended only to 1 degree of a great circle, or 60 geographical miles; 15,000*l.* if found to 40 ſuch miles; and 20,000*l.* to the perſon that can find it within 30 minutes of a great circle, or 30 geographical miles.

We cannot enter fully into this ſubject in theſe eſſays; it will, I hope, be deemed ſufficient, if we give ſuch an account as will enable the reader to form a general idea of the ſolution of this important problem.

From what has been ſeen in the preceding pages, it is evident that 15 degrees in longitude anſwer to one hour in time, and conſequently that the longitude of any place would be known, if we knew their difference in time; or in other words, how much ſooner the ſun, &c. arrives at the meridian of one place, than that of another. The hours and degrees being in this reſpect commenſurate, it is as proper to expreſs the diſtance of any place in time, as in degrees.

Now it is clear, that this difference in time would be eaſily aſcertained by the obſervation of any inſtantaneous appearance in the heavens, at two diſtant places; for the difference in time at which the ſame phænomenon is obſerved,

ved, will be the diſtance of the two places from each other in longitude; on this principle, moſt of the methods in general uſe are founded.

Thus if a clock, or watch, was ſo contrived, as to go uniformly in all ſeaſons, and in all places; ſuch a watch being regulated to London time, would always ſhew the time of the day at London; then the time of the day under any other meridian being found, the difference between that time, and the correſponding London time, would give the difference in longitude.

For ſuppoſing any perſon poſſeſſed of one of theſe time-pieces, to ſet out on a journey from London, if his time-piece be accurately adjuſted, wherever he is, he will always know the hour at London exactly; and when he has proceeded ſo far either eaſtward or weſtward, that a difference is perceived betwixt the hour ſhewn by his time-piece, and thoſe of the clocks and watches at the places to which he goes, the diſtance of thoſe places from London in longitude will be known. But to whatever degree of perfection ſuch movements may be made, yet as every mechanical inſtrument is liable to be injured by various accidents, other methods are obliged to be uſed, as the eclipſes of the ſun and moon, or of Jupiter's ſatellites. Thus ſuppoſing the moment of the beginning of an eclipſe was at ten o'clock at night at London,

London, and by accounts from two obſervers in two other places, it appears that it began with one of them at nine o'clock, and with the other at midnight; it is plain, that the place where it began at nine is one hour, or 15 degrees eaſt in longitude from London; the other place where it began at midnight, is 30 degrees diſtant in weſt longitude from London. Eclipſes of the ſun and moon do not, however, happen often enough to anſwer the purpoſes of navigation; and the motion of a ſhip at ſea prevents the obſervations of thoſe of Jupiter's ſatellites.

If the place of any celeſtial body be computed, for example, as in an almanack, for every day or to parts of days, to any given meridian; and the place of this celeſtial body can be found by obſervation at ſea, the difference of time between the time of obſervation and the computed time, will be the difference of longitude in time. The moon is found to be the moſt proper celeſtial object, and the obſervations of her appulſes to any fixed ſtar is reckoned one of the beſt methods for reſolving this difficult problem.

Length of the Degrees of Longitude.

Suppoſing the earth to be a perfect globe, the length of a degree upon the meridian has been eſtimated to be 69,1 miles; but as the earth is

an

an oblate ſpheroid, the length of a degree on the equator will be ſomewhat greater.

Whether the earth be conſidered as a ſpheroid or a globe, all the meridians interſect one another at the poles. Therefore, the number of miles in a degree muſt always decreaſe as you go north or ſouth from the equator. This is evident by inſpection of a globe, where the parallels of latitude are found to be ſmaller in proportion as they are nearer the pole. Hence it is that a degree of longitude is no where the ſame, but upon the ſame parallel; and that a degree of longitude is equal to a degree of latitude only upon the equator.

The following TABLE ſhews how many geographical miles, and decimal parts of a mile, would be contained in a degree of longitude, at each degree of latitude from the equator to the poles, if the earth was a perfect ſphere, and the circumference of it's equinoctial line 360 degrees, and each degree 60 geographical miles.

This table enables us to determine the velocity with which places upon the globe revolve eaſtward; for the velocity is different, according to the diſtance of the places from the equator, being ſwifteſt as paſſing through a greater ſpace, and ſo by degrees ſlower towards the poles, as paſſing through a leſs ſpace in the ſame time. Now as every part of the earth is moved through the ſpace of it's circumference, or 360

degrees in 24 hours; the ſpace deſcribed in one hour is found by dividing 360 by 24, which gives in the quotient 15 degrees; and ſo many degrees does every place on the earth move in an hour. The number of miles contained in ſo many degrees in any latitude, is readily found from the table.

Thus under the equator places revolve at the rate of more than 1000 miles in an hour; at London, at the rate of about 640 miles in an hour.

T A B L E.

LAT. Deg.	Miles.	LAT. Deg.	Miles.	LAT. Deg.	Miles.
00	60,00	17	57,37	34	49,74
1	59,99	18	57,06	35	49,15
2	59,96	19	56,73	36	48,54
3	59,92	20	56,38	37	47,92
4	59,86	21	56,01	38	47,28
5	59,77	22	55,63	39	46,62
6	59,67	23	55,23	40	45,95
7	59,56	24	54,81	41	45,28
8	59,42	25	54,38	42	44,59
9	59,26	26	53,93	43	43,88
10	59,08	27	53,46	44	43,16
11	58,89	28	52,97	45	42,43
12	58,68	29	52,47	46	41,68
13	58,46	30	51,96	47	40,92
14	58,22	31	51,43	48	40,15
15	57,95	32	50,88	49	39,36
16	57,67	33	50,32	50	38,57

LAT.		LAT.		LAT.	
Deg.	*Miles.*	*Deg.*	*Miles.*	*Deg.*	*Miles.*
51	37,76	65	25,36	79	11,45
52	36,94	66	24,41	80	10,42
53	36,11	67	23,45	81	9,38
54	35,26	68	22,48	82	8,35
55	34,41	69	21,50	83	7,32
56	33,55	70	20,52	84	6,28
57	32,68	71	19,54	85	5,23
58	31,79	72	18,55	86	4,18
59	30,90	73	17,54	87	3,14
60	30,00	74	16,53	88	2,09
61	29,09	75	15,52	89	1,05
62	28,17	76	14,51	90	0,00
63	27,24	77	13,50		
64	26,30	78	12,47		

Another circumſtance which ariſes from this difference of meridians in time, muſt detain us a little before we quit this ſubject. For from this difference it follows, that if a ſhip ſails round the world, always directing her courſe eaſtward, ſhe will at her return home find ſhe has gained one whole day of thoſe that ſtayed at home; that is, if they reckon it May 1, the ſhip's company will reckon it May 2; if weſtward, a day leſs, or April 30.

This circumſtance has been taken notice of by navigators. "It was during our ſtay at Mindanao (ſays Capt. Dampier) that we were firſt made ſenſible of the change of time in the courſe of our voyage: for having travelled ſo

far weſtward, keeping the ſame courſe with the ſun, we conſequently have gained ſomething inſenſibly in the length of the particular days, but have loſt in the tale the bulk or number of the days or hours.

"According to the different longitudes of England and Mindanao, this iſle being about 210 degrees weſt from the Lizard, the difference of time at our arrival at Mindanao, ought to have been about fourteen hours; and ſo much we ſhould have anticipated our reckoning, having gained it by bearing the ſun company.

"Now the natural day in every place muſt be conſonant to itſelf; but going about with, or againſt the ſun's courſe, will of neceſſity make a difference in the calculation of the civil day, between any two places. Accordingly, at Mindanao, and other places in the Eaſt Indies, we found both natives and Europeans reckoning a day before us. For the Europeans coming eaſtward, by the Cape of Good Hope, in a courſe contrary to the ſun and us, wherever we met, were a full day before us in their accounts.

"So among the Indian Mahometans, their Friday was Thurſday with us; though it was Friday alſo with thoſe that came eaſtward from Europe.

"Yet at the Ladrone iſlands we found the Spaniards of Guam keeping the ſame computation with ourſelves; the reaſon of which I take to be, that they ſettled that colony by a courſe weſt-

weſtward from Spain; the Spaniards going firſt to America, and thence to the Ladrone iſlands."

It is clear, from what has been ſaid in the firſt part of this article, concerning both latitude and longitude, that if a perſon travel ever ſo far directly towards eaſt or weſt, his latitude would be always the ſame, though his longitude would be continually changing.

But if he went directly north or ſouth, his longitude would continue the ſame, but his latitude would be perpetually varying.

If he went obliquely, he would change both his latitude and longitude.

The longitude and latitude of places give only their relative diſtances on the globe; to diſcover, therefore, their real diſtance, we have recourſe to the following problem.

PROBLEM X.

Any place being given, to find the diſtance of that place from another, in a great circle of the earth.

We ſhall divide this problem into three caſes.

Caſe 1. If the places lie under the ſame meridian. Bring them up to the meridian, and mark the number of degrees intercepted between them. Multiply the number of degrees thus found by 60, and they will give the number of

geographical miles between the two places. But if we would have the number of English miles, the degrees before found must be multiplied by $69\frac{1}{2}$.

Case 2. If the places lie under the equator. Find their difference of longitude in degrees, and multiply as in the preceding case, by 60, or $69\frac{1}{2}$.

Case 3. If the places lie neither under the same meridian, nor under the equator. Then lay the quadrant of altitude over the two places, and mark the number of degrees intercepted between them. These degrees multiplied as above-mentioned, will give the required distance.

Of a Parallel Sphere.

A parallel sphere is that position of the globe, in which the poles are in their zenith and nadir, it's axis at right angles to the equator and horizon, which coincide; consequently, those circles which are parallel to the equator, are also parallel to the horizon.

The inhabitants that answer to this position of the sphere, if any there be, must live upon the two terrestrial poles, and will have but one day and one night throughout the year, each six months long. The day, to those who live under the north pole, begins when the sun enters Aries, and continues till he reaches Libra, when night commences, and continues the other six

ſix months. Thoſe who live under the ſouth pole, experience the direct contrary; but both enjoy a long continuance of twilight, after the ſun has departed from them, and before he appears again.

For half a year, the inhabitants of the pole ſee the ſun moving continually round above their horizon, in a kind of ſpiral line; when they firſt perceive him, he ſkims, as it were, their horizon, then riſes gradually higher, till he reaches the tropic, when he again deſcends, till he touches the horizon, when their long and gloomy night begins.

During their ſummer's day, the moon appears to them in the heavens only as a white cloud; in the winter, during her ſecond and third quarters, ſhe circulates above the horizon for ſeveral days, without ſetting, being a fortnight above, and a fortnight below the horizon.

They can only ſee the ſtars in that hemiſphere between the pole and the equator; during half a year, none of them are viſible, being ſwallowed up, as it were, by the ſuperior light of the ſun. To them the ſtars never ſet, but move in circles parallel to the horizon, keeping always the ſame altitude. The planets are half their time above, and half below the horizon.

Of a Right Sphere.

A RIGHT SPHERE is that in which the equator is at right angles to the horizon, and therefore

in the zenith and nadir, and in which the poles are in the horizon.

The inhabitants that anſwer to this ſituation of the ſphere, live under the equator; their days and nights are of an equal length throughout the year, being each of them twelve hours in length.

The ſun riſes and ſets nearly perpendicular; he is half a year on one ſide their zenith, and as much on the other, paſſing over it twice a year at the equinoxes.

There is nothing uncommon in the appearance of the moon, but her riſing and ſetting like the ſun, nearly in a perpendicular direction; but there is to theſe inhabitants a moſt glorious diſplay of all the ſtars in the heavens, from pole to pole, all of them riſing and ſetting perpendicular, except the poles which lie in the horizon.

Of an Oblique Sphere.

An oblique sphere is the poſition common to all the inhabitants of the earth, except thoſe who live at the poles, and upon the equator; it is thus named, becauſe the equator cuts the horizon obliquely.

In this ſphere the axis of the earth always makes an acute angle with the horizon; the equator is half above and half below it.

All the parallels to the equator cut the horizon alſo obliquely, and thus make the diurnal arches greater or leſs than the nocturnal ones, excepting at the time of the equinoxes.

Thoſe inhabitants of this ſphere, who live without the tropics, never have the ſun in their zenith; but under the tropics the ſun is vertical once, and between the tropics and the equator twice every year.

In this poſition the ſtars riſe and ſet obliquely; and as the moon, when at full, is always in an oppoſite ſign to the ſun, ſhe is on the ſouth ſide of the equator in ſummer, and conſequently her altitude is low, and her courſe ſhort; but in winter, when at the full, ſhe is in the northern ſigns, making a high long circuit, which is of great uſe in that dreary ſeaſon.

Of the Twilight.

That light which we have from the ſun before it riſes, and after it ſets, is called the TWILIGHT.

The morning twilight, or day-break, commences when the ſun comes within 18 degrees of the horizon, and continues till ſun-riſing. The evening twilight begins at ſun-ſetting, and continues till it is 18 degrees below the horizon.

To illuſtrate the cauſes of the various length of twilight in different places, a wire circle is fixed 18 degrees below the ſurface of the broad

paper

paper circle; ſo that all thoſe places which are above the wire circle will have twilight, but it will be dark to all thoſe places below it.

We have already obſerved, that it is owing to the atmoſphere, that we are favoured with the light of the ſun before he is above, and after he is below our horizon. Hence, though after ſun-ſetting we receive no direct light from the ſun, yet we enjoy it's reflected light for ſome time; ſo that the darkneſs of the night does not come on ſuddenly, but by degrees.

In a right poſition of the ſphere the twilights are quickly over, becauſe the ſun riſes and ſets nearly in a perpendicular; but in an oblique ſphere they laſt longer, the ſun riſing and ſetting obliquely: the greater the latitude of the place, the longer is the duration of the twilight; ſo that all thoſe who are in 49 degrees of latitude have in the ſummer, near the ſolſtice, their atmoſphere enlightened the whole night, the twilight laſting till ſun-riſing.

In a parallel ſphere, the twilight laſts for ſeveral months; ſo that the inhabitants of this poſition have either direct, or reflex light of the ſun nearly all the year, as will plainly appear by the globe.

Of the diurnal Motion of the Earth.

As the daily motion of the earth about it's axis, and the phænomena dependent on it, are ſome

ſome of the moſt eſſential points which a beginner ought to have in view, we ſhall now endeavour to explain them by the globes; and here, I think, the advantage of globes mounted in my father's manner, over thoſe generally uſed, will be very evident.

We have already obſerved, that in globes mounted in our manner, the motion of the terreſtrial globe about it's axis repreſents the diurnal motion of the earth, and that the horary index will point out upon the equator the 24 hours of one diurnal rotation, or any part of that time.

We ſhall now conſider the broad paper circle as the plane which diſtinguiſhes light from darkneſs; that is, the enlightened half of the earth's ſurface, from that which is not enlightened.

For when the ſun ſhines upon a globe, he ſhines only upon one half of it; that is, one half of the globe's ſurface is enlightened by him, the other not.

That the enlightened half may be that half which is above the broad paper circle, we muſt imagine the ſun to be in our ZENITH.

Or let a ſun be painted on the ceiling over the terreſtrial globe, the diameter of the picture equal to the diameter of the globe.

Then all thoſe places that are above the broad paper circle, will be in the ſun's light; that is, it will be DAY in all thoſe places.

And

And all places that are below this circle, will be out of the ſun's light; that is, in all thoſe places it will be NIGHT.

When any place on the earth's ſurface comes to the edge of the broad paper circle, paſſing out of the ſhade into the light, the ſun will appear RISING at that place.

And when a place is at the edge of the broad paper circle, going out of the light into the ſhade, the ſun will appear at that place to be SETTING.

When we view the globe in this poſition, we at once ſee the ſituation of all places in the illuminated hemiſphere, whoſe inhabitants enjoy the light of the day. One edge of the broad paper circle ſhews at what place the ſun appears riſing at the SAME time. And the oppoſite edge ſhews at what places the ſun is ſetting at the ſame time.

The horary index ſhews how long a place is moving from one edge to the other; that is, how long the day or night is at that place.

TO RECTIFY THE TERRESTRIAL GLOBE.

To rectify the terreſtrial globe, is to place it in the ſame poſition in which our earth ſtands to the ſun, at all or any given times.

That half of the earth's ſurface, which is enlightened by the ſun, is not always the ſame; it differs according as the ſun's declination differs.

To

To rectify then the terreſtrial globe, is to bring it into ſuch a poſition, as that the enlightened half of the earth's ſurface may be all above the broad paper circle.

On the back ſide of the ſtrong braſs meridian, and on each ſide of the north pole, the months and days of the month are graduated in two concentric ſpaces, agreeable to the declination of the ſun.

Bring the day of the month that is graduated, on the back ſide of the ſtrong braſs meridian, to coincide with the broad paper circle, and the globe is rectified.

Thus ſet the firſt of May to coincide with the broad paper circle, and that half of the earth's ſurface which is enlightened at any time upon that day, will be all at once above the ſaid circle.

If the horary index be ſet to XII when any particular place is brought under the ſtrong braſs meridian, it will ſhew the preciſe time of ſun-riſing and ſun-ſetting at that place.

It will alſo ſhew how long any place is in moving from the eaſt to the weſt ſide of the illuminated diſc, and thence the length of the day and night.

It will alſo point out the length of the twilight, by ſhewing the time in which the place is paſſing from the twilight circle to the edge of the broad paper circle on the weſtern ſide; or from the edge of this circle on the eaſtern ſide,

to the twilight wire, and thus determine the length of the whole artificial day.

N. B. The twilight wire is placed at 18 degrees from the broad paper circle.

We ſhall now proceed to exemplify upon the globes theſe particulars, at three different ſeaſons of the year, viz. the ſummer ſolſtice, the winter ſolſtice, and the time or times of the equinoxes.

PROBLEM XI.

To place the globe in the ſame ſituation, with reſpect to the ſun, as our earth is in at the time of the ſummer ſolſtice.

Rectify the globe to the extremity of the diviſions for the month of June, or 23½ degrees north declination; that is, bring theſe diviſions on the ſtrong braſs meridian to coincide with the plane of the broad paper circle.

Then that part of the earth's ſurface, which is within the northern polar circle, will be above the broad paper circle, and will be in the light, and the inhabitants thereof will have no night.

But all that ſpace which is contained within the ſouthern polar circle, will continue in the ſhade; that is, it will there be continual night.

In this poſition of the globe, the pupil will obſerve how much the diurnal arches of the parallels of latitude decreaſe, as they are more and more diſtant from the elevated pole.

If any place be brought under the ſtrong braſs meridian, and the horary index is ſet to that XII which is moſt elevated, and the place be afterwards brought to the weſtern ſide of the broad paper circle, the hour index will ſhew the time of ſun-riſing; and when the place is moved to the eaſtern edge, the index points to the time of ſun-ſetting.

The length of the day is obtained by the time ſhewn by the horary index, while the globe moves from the weſt to the eaſt ſide of the broad paper circle.

Thus it will be found, that at London the ſun riſes about 15 minutes before IV in the morning, and ſets about 15 minutes after VIII at night.

At the following places, it will be nearly at the times expreſſed in the table.

	☉ Riſing		☉ Setting		Length of day.		Twi-light.	
	h.	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*
Cape Horn - -	8	44	3	16	6	32	2	35
Cape of Good Hope	7	9	4	51	9	42	1	43
Rio de Janeiro, in Brazil	6	42	5	19	10	38	1	23
Iſland of St. Thomas, near the equator -	6		6		12		1	20
Cape Lucas, California	5	12	6	48	13	36	1	35

We alſo ſee, that at the ſame time the ſun is riſing at London, it is riſing at the iſles of Sicily and Madagaſcar.

And, that at the time when the ſun ſets at Lon-

London, it is ſetting at the iſland of Madeira, and at Cape Horn.

And when the ſun is ſetting at the iſland of Borneo, in the Eaſt Indies, it is riſing at Florida, in America. And many other ſimilar circumſtances relative to other places, are ſeen as it were by inſpection.

PROBLEM XII.

To explain the ſituation of the earth, with reſpect to the ſun, at the time of the winter ſolſtice.

Rectify the globe to the extremity of the diviſions for the month of December, or to $23\frac{1}{2}$ degrees ſouth declination.

When it will be apparent that the whole ſpace within the ſouthern polar circle is in the ſun's light, and enjoys continual day; whilſt that of the northern polar circle is in the ſhade, and has continual night.

If the globe be turned round, as before, the horary index will ſhew, that at the ſeveral places before-mentioned their days will be reſpectively equal to what their nights were at the time of the ſummer ſolſtice.

It will appear farther, that it is now ſun-ſetting at the ſame time in thoſe places, in which it was ſun-riſing at the ſame time at the ſummer ſolſtice. And on the contrary, ſun-riſing at the time it then appeared to ſet.

PROBLEM

PROBLEM XIII.

To place the globe in the ſituation of the earth, at the times of the equinox.

The ſun has no declination at the times of the equinox, conſequently there muſt be no elevation of the pole.

Bring the day of the month when the ſun enters the firſt point of Aries, or day of the month when the ſun enters the firſt point of Libra, to the plane of the broad paper circle; then the two poles of the globe will be in that plane alſo, and the globe will be in the poſition which is called a RIGHT SPHERE.

For it is a right ſphere when the two poles are in the plane of the broad paper circle, becauſe then all thoſe circles which are parallel to the equator will be at right angles to that plane.

If the globe be now turned from weſt to eaſt, it will plainly appear, that all places upon it's ſurface are twelve hours above the broad paper circle, and twelve hours below it; that is, the days are twelve hours long all over the earth, and that the nights are equal to the days, whence theſe times are called the times of equinox.

Two of theſe occur in every year; the firſt is the autumnal, the ſecond the vernal equinox.

At theſe ſeaſons the ſun appears to riſe at the ſame time to all places that are on the ſame me-

ridian. The ſun ſets alſo at the ſame time in all thoſe places.

Thus if London and Mundford, on the gold coaſt, be brought to the ſtrong braſs meridian, the graduated ſide of which is in this caſe the horary index, and they be afterwards carried to the weſtern edge of the broad paper circle, the index will ſhew that the ſun riſes at VI at both places; when they are carried to the eaſtern edge, the index points to VI for the time of ſun-ſetting.

N. B. If London be not the given place, the hour index is to be ſet to the moſt elevated XII, while the place is under the graduated edge of the ſtrong braſs meridian.

The following circumſtances, which uſually attend the four cardinal diviſions of the year, cannot be better introduced than at this place. At the time of the equinoxes, when the ſun paſſes from one hemiſphere into the other, there is almoſt conſtantly ſome diſturbance in the weather; the winds are then generally higher: at the vernal equinox they are for the moſt part eaſterly, cold, dry, and ſearching. The ſolſtitial point of the ſummer is often diſtinguiſhed by violent rains, and what we call a midſummer flood. The winter being leſs rainy than the ſummer, nothing particular happens at the winter ſolſtice, but that the froſts commonly ſet in more

more ſeverely, with ſome quantity of ſnow upon the ground.

OF THE ARTIFICIAL, OR TERRESTRIAL HORIZON.

The braſs circle, which may be ſlipped from pole to pole on the moveable meridian, has been already deſcribed, page 245. The circumference of it is divided into eight parts, to which are affixed the initial letters of the mariner's compaſs.

When the center of it is ſet to any particular place, the ſituation of any other place is ſeen, with reſpect to that place; that is, whether they be eaſt, weſt, north, or ſouth of it.

It will, therefore, repreſent the horizon of that place.

We ſhall here uſe this artificial horizon, to ſhew why the ſun, although he be always in one and the ſame place, appears to the inhabitants of the earth at different altitudes, and in different azimuths.

PROBLEM XIV.

To exemplify the ſun's altitude, as obſerved with an artificial horizon.

The altitude of the ſun is greater or leſs, according as the line which goes from us to the ſun is nearer to, or farther off from our horizon.

Let the moveable circle be applied to any

place, as London, then will the horizon of London be thereby reprefented.

The fun is fuppofed, as before, to be in the zenith, that is, directly over the terreftrial globe.

If then from London a line go vertically upwards, the fun will be feen at London in that line.

At fun-rifing, when London is brought to the weft edge of the broad paper circle, the fuppofed line will be parallel to the artificial horizon, and the fun will then be feen in the horizon.

As the globe is gradually turned from the weft towards the eaft, the horizon will recede from that line which goes from London vertically upwards; fo that the line in which the fun is feen, gets further and further from the horizon; that is, the fun's altitude increafes gradually.

When the horizon, and the line which goes from London vertically upwards, are arrived at the ftrong brafs meridian, the fun is then at his greateft or meridian altitude for that day, and the line and horizon are at the largeft angle they can make with each other.

After this, the motion of the globe being continued, the angle between the artificial horizon, and the line which goes from London vertically upwards, continually decreafes, until London arrives at the eaftern edge of the broad paper circle; it's horizon then becomes vertical again, and parallel to the line which goes vertically

upwards.

upwards. The ſun will again appear in the horizon, and will ſet.

PROBLEM XV.

Of the ſun's meridian altitude, at the three different ſeaſons.

Rectify the globe to the time of the winter ſolſtice, by problem xii. and place the center of the viſible horizon on London.

When London is at the graduated edge of the ſtrong braſs meridian, the line which goes vertically upwards makes an angle of about 15 degrees; this is the ſun's meridian altitude at that ſeaſon, to the inhabitants of London.

If the globe be rectified to the times of equinox, by problem xii. the horizon will be farther ſeparated from the line which goes vertically upwards, and makes a greatér angle therewith, it being about 38½ degrees; this is the ſun's meridian altitude, at the time of equinox at London.

Again, rectify to the ſummer ſolſtice by prob. xi. and you will find the artificial horizon recede farther from the line which goes from London vertically upwards, and the angle it then makes is about 62 degrees, which ſhews the ſun's meridian altitude at the time of the ſummer ſolſtice.

Hence flows alſo the following arithmetical problem.

PROBLEM XVI.

To find the ſun's meridian altitude univerſally.

Add the ſun's declination to the elevation of the equator, if the latitude of the place, and the declination of the ſun are both on the ſame ſide.

If on contrary ſides, ſubtract the declination from the elevation of the equator, and you obtain the ſun's meridian altitude.

Thus the elevation of the equator at London is -	38°. 28
The ſun's declination on the 20th of May - -	20 8
Their ſum, the ſun's meridian altitude that day - -	58 36

Again, to the elevation of the equator at London - -	38° 28
Add the ſun's greateſt declination at the time of the ſummer ſolſtice -	23 29
The ſum is the ſun's greateſt meridian altitude at London -	61 57

PROBLEM XVII.

Of the ſun's azimuths, as compared with the artificial horizon.

The artificial horizon ſerves alſo to determine the ſun's azimuths.

An

An AZIMUTH of the ſun is denominated from that point of the horizon, to which the ſun, or a line going to the ſun, is neareſt.

Thus if the ſun, or a line going to the ſun, be neareſt the ſouth-eaſt point of the horizon, which point is 45 degrees diſtant from the meridian, the ſun's azimuth is an azimuth of 45 degrees, and the ſun will appear in the ſouth-eaſt.

Imagine the ſun, as we have done before, to be placed directly over the globe.

In which caſe, a line going to the ſun from any place on the ſurface of the globe, will have a vertical direction, and will go from that place vertically upwards.

If then we apply the artificial horizon to any place, the point of this horizon to which a vertical line is neareſt, ſhews the ſun's azimuth at that time.

It is obſervable, that the point of the horizon to which ſuch a vertical line is neareſt, will be at all times that point which is moſt elevated.

To exemplify this, let the globe be in the poſition of a right ſphere, and let the artificial horizon be applied to London.

When London is at the weſtern edge of the broad paper circle, which ſituation repreſents the time when the ſun appears to riſe, the eaſtern point of the artificial horizon being then moſt elevated, ſhews that the ſun at his riſing is due eaſt.

Turn the globe, till London comes to the eaſtern edge of the broad paper circle, then the weſtern point of the artificial horizon will be moſt elevated, ſhewing that the ſun ſets due weſt.

Now place the globe in the poſition of an oblique ſphere; and if London be brought to the eaſtern or weſtern ſide of the broad paper circle, the vertical line will depart more or leſs from the eaſt and weſt points, in which caſe the ſun is ſaid to have more or leſs AMPLITUDE.

If the departure be northward, it is called northern amplitude; if ſouthward, it is called ſouthern amplitude.

In whatever poſition the globe be placed,* when London comes to the ſtrong braſs meridian, the moſt elevated part of the artificial horizon will be the ſouth point of it.

Which ſhews that at noon the ſun will always, and in all ſeaſons, appear in the ſouth.

OF THE ANCIENT DIVISIONS OF THE EARTH INTO ZONES AND CLIMATES.

Climates was a term uſed by the ancient aſtronomers to expreſs a diviſion of the earth, which, before the marking down the latitudes of countries into degrees and minutes were in uſe, ſerved them

* The globe is not ſuppoſed in this caſe, or under this view of things, ever to be elevated above the limits of the ſun's declination.

them for dividing the earth into certain portions in the ſame direction, ſo as to ſpeak of any particular place with ſome degree of certainty, though not with due preciſion.

It was natural for the earlieſt obſervers to remark, for one of the firſt things, the diverſity that there was in the ſun's riſing and ſetting: it was by this they regulated what they called climates; which are a tract on the ſurface of the earth, of various breadths, being regulated by the different lengths of time between the riſing and ſetting of the ſun in the longeſt day, in different places.

From the equator to the latitude 66½ north and ſouth, a climate is conſtituted by the difference of half an hour in the length of the longeſt day, and this is ſufficient for underſtanding the ancients. Between the polar circle and the pole, the length of the longeſt day, in one parallel, exceeds the length of the longeſt in the next by a month; but of theſe the ancients knew nothing.

CLIMATES BETWEEN THE EQUATOR AND POLAR CIRCLES.

Climates.	Hours.	Latitude.		Breadth.		Climates.	Hours.	Latitude.		Breadth.	
		D.	M.	D.	M.			D.	M.	D.	M.
1	12	8	25	8	25	5	14½	36	28	6	08
2	13	16	25	8	00	6	15	41	22	4	54
3	13½	23	50	7	25	7	15½	45	29	4	07
4	14	30	25	6	30	8	16	49	01	3	32

CLIMATES

CLIMATES CONTINUED.

Climates.	Hours.	Latitude. D.	Latitude. M.	Breadth. D.	Breadth. M.	Climates.	Hours.	Latitude. D.	Latitude. M.	Breadth. D.	Breadth. M.
9	16½	52	00	2	57	17	20½	64	06	0	44
10	17	54	27	2	29	18	21	64	49	0	43
11	17½	56	37	2	10	19	21½	65	21	0	32
12	18	58	29	1	52	20	22	65	47	0	22
13	18½	59	58	1	29	21	22½	66	06	0	19
14	19	61	18	1	20	22	23	66	20	0	14
15	19½	62	25	1	07	23	23½	66	28	0	08
16	20	63	22	0	57	24	24	66	31	0	03

Therefore, to difcover in what climate a place is, whofe latitude does not exceed 66½ degrees, find the length of the longeft day in that place, and fubtracting 12 hours from that length, the number of half hours in the remainder will fpecify the climate.

ZONES.

Zones is another divifion of the earth's furface ufed by the ancients: that part which the fun paffes over in a year comprehending 23½ degrees on each fide the equator, was called by the ancients the torrid zone. The two frigid zones are contained between the polar circles. Between the torrid and the two frigid zones are contained the two temperate ones, each being about 43 degrees broad.

The latitude of a place being the mark of it's pofition with refpect to the fun, may be con-

ſidered as a general index to the temperature of the climate: it is, however, liable to very great exceptions; but to deny it abſolutely, would be to deny that the ſun is the ſource of light and heat below.

Nothing can be more hideous or mournful, than the pictures which travellers preſent us of the polar regions; the ſeas ſurrounding inhoſpitable coaſts, are covered with iſlands of ice, that have been increaſing for many centuries: ſome of theſe iſlands are immerſed ſix hundred feet under the ſurface of the ſea, and yet often rear up alſo their icy heads more than one hundred feet above it's level, and are three or four miles in circumference. The following account will give ſome idea of the ſcenery produced by arctic weather. At Smearingborough-Harbour, within 15 degrees of the pole, the country is full of mountains, precipices, and rocks; theſe are covered with ice and ſnow: in the vallies are hills of ice, which ſeem daily to accumulate: theſe hills aſſume many ſtrange and fantaſtic appearances; ſome looking like churches or caſtles, ruins, ſhips in full ſail, whales, monſters, and all the various forms that fill the univerſe: there are ſeven of theſe ice-hills, which are the higheſt in the country; when the air is clear and the light ſhines full upon them, the proſpect is inconceivably brilliant; the ſun is reflected from them as from glaſs; ſometimes they appear of a bright hue,

hue, like ſapphire; ſometimes variegated with all the glories of the priſmatic colours, exceeding, in the magnitude of luſtre and beauty of colour, the richeſt gems in the world; diſpoſed in ſhapes wonderful to behold, dazzling the eye with the brilliancy of it's ſplendor. At Spitſbergen, within 10 degrees of the pole, the earth is locked up in ice till the middle of May; in the beginning of July the plants are in flower, and perfect their ſeeds in a month's time. For though the ſun is much more oblique in the higher latitudes than with us, his long continuance above the horizon is attended with an accumulation of heat exceeding that of many places under the torrid zone; and there is reaſon to ſuppoſe, that the rays of the ſun, at any given altitude, produce greater degrees of heat in the condenſed air of the polar regions, than in the thinner air of this climate.

Yet, if we look for heat, and the remarkable effects of it, we muſt go to the countries near the equator, where we ſhall find a ſcenery totally different from that of the frigid zone. Here all things are upon a larger ſcale than in the temperate climates; their days are burning hot, in ſome parts their nights are piercing cold, their rains laſting and impetuous, like torrents; their dews exceſſive, their thunder and lightning more frequent, terrible, and dangerous; the heat burns up the lighter ſoil, and forms it into a ſandy

a ſandy deſert, while it quickens all the moiſter tracts with incredible vegetation.

The ancients ſuppoſed that the frigid zone was uninhabitable from cold, and the torrid from the intolerable heat of the ſun; we now, however, know that both are inhabited; the ſentiments of the ancients therefore, in this reſpect, are a proof how inadequate the faculties of the human mind are to diſcuſſions of this nature when unaſſiſted by facts.

PROBLEM XVIII.

To illuſtrate the ancient diſtinction of different places on the earth, according to the diverſity of the ſhadows of upright bodies at noon.

When the ſun at noon is in the zenith of any place, the inhabitants of that place were by the ancients called ASCII; that is, without ſhadow; for the ſhadow of a man ſtanding upright, when the ſun is directly over his head, is not extended beyond that part of the earth which is directly under his body, and therefore will not be viſible.

As the ſhadow of every opake body is extended from the ſun, it follows, that when the ſun at noon is ſouthward from the zenith of any place, the ſhadow of an inhabitant of that place, and indeed of any other opake body, is extended towards the north.

But when the ſun is northward from the zenith of any place, the ſhadow falls towards the ſouth.

Thoſe

Thofe are called AMPHISCII, that have both kinds of meridian fhadows.

Thofe whofe meridian fhadows are always projected one way, are termed HETEROSCII.

Rectify the globe to the fummer folftice, and move the artificial horizon to the equator, the north point will be the moft elevated at noon.

Which fhews, that to thofe inhabitants who live at the equator, the fun will at this feafon appear to the north at noon, and their fhadow will therefore be projected fouthwards.

But if you rectify the globe to the winter folftice, the fouth point being then the uppermoft point at noon, the fame perfons will at noon have the fun on the fouth fide of them, and will project their fhadows northwards.

Thus they are amphifcii, projecting their fhade both ways, which is the cafe of all the inhabitants within the tropics.

The artificial horizon remaining as before, rectify the globes to the times of the equinox, and you will find that when this horizon is under the ftrong brafs meridian, a line going vertically upwards will be perpendicular to it, and confequently the fun will be directly over the heads of the inhabitants, and they will be afcii, having no noon fhade; their fhadow is in the morning projected directly weftward, in the evening directly eaftward.

The

The ſame thing will alſo happen to all the inhabitants who live between the tropics of Cancer and Capricon, ſo that they are not only aſcii, but amphiſcii alſo.

Thoſe who live without the tropics are heteroſcii; thoſe in north latitude have the noon ſhade always directed to the north, while thoſe in ſouth latitude have it always projected to the ſouth.

The inhabitants of the polar circles are called PERISCII, becauſe as the ſun goes round them continually, their ſhade goes round them likewiſe.

PROBLEM XIX.

Of the ANTŒCI, PERIŒCI, and ANTIPODES.

Theſe terms being often mentioned by ancient geographical writers to expreſs the different ſituation of parts of the globe, by the relation which the ſeveral inhabitants bore to one another; it will be neceſſary to take ſome notice of them.

The ANTŒCI are two nations which are in or near the ſame meridian, the one in north, the other in ſouth latitude.

They have therefore, the ſame longitude, but not the ſame latitude; oppoſite ſeaſons of the year, but the ſame hour of the day; the days of the one are equal to the nights of the other, and

and vice verſa ; when the days of the one are at the longeſt, they are ſhorter at the other.

When they look towards each other, the ſun ſeems to riſe on the right hand of the one, but on the left of the other. They have different poles elevated, and the ſtars that never ſet to the one, are never ſeen by the other.

Periœci are alſo two oppoſite nations, ſituated on the ſame parallel of latitude.

They have, therefore, the ſame latitude, but differ 180 degrees in longitude ; the ſame ſeaſons of the year, but oppoſite hours of the day ; for when it is twelve at night to the one, it is twelve at noon with the other. On the equinoctial days, the ſun is riſing to one, when it is ſetting to the other.

Antipodes are two nations diametrically oppoſite, which have oppoſite ſeaſons and latitude, oppoſite hours and longitude.

The ſun and ſtars riſe to the one, when they ſet to the other, and that during the whole year, for they have the ſame horizon.

The day of the one is the night of the other, and when the day is longeſt with the one, the other has it's ſhorteſt day.

They have contrary ſeaſons at the ſame time ; different poles, but equally elevated ; and thoſe ſtars that are always above the horizon of one, are always under the horizon of the other.

To exemplify theſe particulars, bring the given

given place to the ſtrong braſs meridian; then in the oppoſite hemiſphere, and under the ſame degree of latitude with the given place, you will find the antœci.

The given place remaining under the meridian, ſet the horary index to XII; then turn the globe, till the other XII is under the index, then will you find the periœci under the ſame degree of latitude with the given place.

Thus the inhabitants of the ſouth part of Chili are antœci to the people of New England, whoſe periœci are thoſe Tartars who dwell on the north borders of China, which Tartars have the ſaid inhabitants of Chili for their antipodes.

This will become evident, by placing the globe in the poſition of a right ſphere, and bringing thoſe nations to the edge of the broad paper circle.

PROBLEM XX.

The day of the month being given, to find all thoſe places on the globe, over whoſe zenith the ſun will paſs on that day.

Rectify the terreſtrial globe, by bringing the given day of the month on the back ſide of the ſtrong braſs meridian, to coincide with the plane of the broad paper circle; obſerve the number of degrees of the braſs meridian, which correſponds to the given day of the month.

This number of degrees, counted from the equator on the ſtrong braſs meridian, towards the elevated pole, is the point over which the ſun is vertical; and all thoſe places which paſs under this point, have the ſun directly vertical on the given day.

Example. Bring the 11th of May to coincide with the plane of the broad paper circle, and the ſaid plane will cut 18 degrees for the elevation of the pole, which is equal to the ſun's declination for that day, which being counted on the ſtrong braſs meridian towards the elevated pole, is the point over which the ſun will be vertical; and all places that are under this degree, will have the ſun on their zenith on the 11th of May.

Hence, when the ſun's declination is equal to the latitude of any place in the torrid zone, the ſun will be vertical to thoſe inhabitants that day; which furniſhes us with another method of ſolving this problem.

PROBLEM XXI.

To find the ſun's place on the broad paper circle.

Conſider whether the year in which you ſeek the ſun's place is biſſextile, or whether it is the firſt, ſecond, or third year after.

If

If it be the firſt year after biſſextile, thoſe diviſions to which the numbers for the days of the month are affixed, are the diviſions which are to be taken for the reſpective days of each month of that year at noon; oppoſite to which, in the circle of twelve ſigns, is the ſun's place.

If it be the ſecond year after biſſextile, the firſt quarter of a day backwards, or towards the left hand, is the day of the month for that year, againſt which, as before, is the ſun's place.

If it be the third year after biſſextile, then three quarters of a day backwards is the day of the month for that year, oppoſite to which is the ſun's place.

If the year in which you ſeek the ſun's place be biſſextile, then three quarters of a day backwards is the day of the month from the 1ſt of January to the 28th of February incluſive. The intercalary, or 29th day, is three-fourths of a day to the left hand from the 1ſt of March, and the 1ſt March itſelf one quarter of a day forward, from the diviſion marked 1; and ſo for every day in the remaining part of the leap-year; and oppoſite to theſe diviſions is the ſun's place.

In this manner the intercalary day is very well introduced every fourth year into the calendar, and the ſun's place very nearly obtained, according to the Julian reckoning.

Thus,

A. D.		Sun's place.	Apr. 25.	
1788	Biſſextile - -	♉	5°	35
1789	Firſt year after -	♉	5	21
1790	Second - - -	♉	5	6
1791	Third - -	♉	4	55

Upon my father's globes there are twenty-three parallels, drawn at the diſtance of one degree from each other on both ſides the equator, which with two other parallels at 23½ deg. diſtance, include the ecliptic circle.

The two outermoſt circles are called the tropics; that on the north ſide of the equator is called the tropic of Cancer, that which is on the ſouth ſide, the tropic of Capricorn.

Now as the ecliptic is inclined to the equator, in an angle of 23½ degrees, and is included between the tropics, every parallel between theſe muſt croſs the ecliptic in two points, which two points ſhew the ſun's place when he is vertical to the inhabitants of that parallel; and the days of the month upon the broad paper circle anſwering to thoſe points of the ecliptic, are the days on which the ſun paſſes directly over their heads at noon, and which are ſometimes called their two midſummer days.

It is uſual to call the ſun's diurnal paths parallels to the equator, which are therefore aptly repreſented by the above-mentioned parallel circles; though his path is properly a ſpiral line, which

which he is continually defcribing all the year, appearing to move daily about a degree in the ecliptic.

PROBLEM XXII.

To find the fun's declination, and thence the parallel of latitude correfponding thereto.

Find the fun's place for the given day in the broad paper circle, by the preceding problem, and feek that place in the ecliptic line upon the globe; this will fhew the parallel of the fun's declination among the above-mentioned dotted lines, which is alfo the correfponding parallel of latitude; therefore, all thofe places through which this parallel paffes, have the fun in their zenith at noon on the given day.

Thus on the 23d of May the fun's declination will be about 20 deg. 10 min.; and upon the 23d of Auguft it will be 11 deg. 13 min. What has been faid in the firft part of this problem, will lead the reader to the folution of the following.

PROBLEM XXIII.

To find the two days on which the fun is in the zenith of any given place that is fituated between the two tropics.

That parallel of declination which paffes through the given place, will cut the ecliptic

line upon the globe in two points, which denote the ſun's place, againſt which, on the broad paper circle, are the days and months required.

PROBLEM XXIV.

The day and hour at any place being given, to find where the ſun is vertical at that time.

Rectify the globe to the day of the month, ſee page 284, and you have the ſun's declination; bring the given place to the meridian, and ſet the hour index to XII; turn the globe, till the index points to the given hour on the equator; then will the place be under the degree of the declination previouſly found.

Let the given place be London, and time the 11th day of May, at 4 min. paſt V in the afternoon; bring the 11th of May to coincide with the broad paper circle, and oppoſite to it you will find 18 degrees of north declination; as London is the given place, you have only to turn the globe, till 4 min. paſt V weſtward of it is on the meridian, when you will find Port-Royal, in Jamaica, under the 18th degree of the meridian, which is the place where the ſun is vertical at that time.

PROBLEM XXV.

The time of the day at any one place being given, to find all thoſe places where at the

ſame

ſame inſtant the ſun is riſing, ſetting, and on the meridian, and where he is vertical; likewiſe, thoſe places where it is midnight, twilight, and dark night; as well as thoſe places in which the twilight is beginning and ending; and alſo to find the ſun's altitude at any hour in the illuminated, and his depreſſion in the obſcure, hemiſphere.

Rectify the globe to the day of the month, on the back ſide of the ſtrong braſs meridian, and the ſun's declination for that day; bring the given place to the ſtrong braſs meridian, and ſet the horary index to XII upon the equator; turn the globe from weſt to eaſt, until the horary index points to the given time. Then

All thoſe places which lie in the plane of the weſtern ſide of the broad paper circle, ſee the ſun riſing, and at the ſame time thoſe on the eaſtern ſide of it ſee him ſetting.

It is noon to all the inhabitants of thoſe places under the upper half of the graduated ſide of the ſtrong braſs meridian, whilſt at the ſame time thoſe under the lower half have midnight.

All thoſe places which are between the upper ſurface of the broad paper circle, and the wire circle under it, are in the twilight, which begins to all thoſe places on the weſtern ſide that

are immediately under the wire circle; it ends at all thofe which are in the plane of the paper circle.

The contrary happens on the eaftern fide; the twilight is juft beginning to thofe places in which the fun is fetting, and it's end is at the place juft under the wire circle.

And thofe places which are under the twilight wire circle have dark night, unlefs the moon is favourable to them.

All places in the illuminated hemifphere have the fun's latitude equal to their diftance from the edge of the enlightened difc, which is known by fixing the quadrant of altitude to the zenith, and laying it's graduated edge over any particular place.

The fun's depreffion is obtained in the fame manner, by fixing the center of the quadrant at the nadir.

PROBLEM XXVI.

To find all thofe places within the polar circles, on which the fun begins to fhine, the time he fhines conftantly, when he begins to difappear, the length of his abfence, as well as the firft and laft day of his appearance to thofe inhabitants; the day of the month, or latitude of the place being given.

Bring the given day of the month on the back fide of the ftrong brafs meridian, to the plane of

of the broad paper circle; the ſun is juſt then beginning to ſhine on all thoſe places which are in the parallel that juſt touches the edge of the broad paper circle, and will for ſeveral days ſeem to ſkim all around, and but a little above their horizon, juſt as it appears to us at it's ſetting; but with this obſervable difference, that whereas our ſetting ſun appears in one part of the horizon only, by them it is ſeen in every part thereof; from weſt to ſouth, thence eaſt to north, and ſo to weſt again.

Or if the latitude be given, elevate the globe to that latitude, and on the back of the ſtrong braſs meridian, oppoſite to the latitude, you obtain the day of the month; then all the other requiſites are anſwered as above.

As the two concentric ſpaces which contain the days of the month on the back ſide of the ſtrong braſs meridian, are graduated to ſhew the oppoſite days of the year, at 180 degrees diſtance; when the given day is brought to coincide with the broad paper circle, it ſhews when the ſun begins to ſhine on that parallel, which is the firſt day of it's appearance above the horizon of that parallel.

And the plane of the broad paper circle cuts the day of the month on the oppoſite concentric ſpace, when the ſun begins to diſappear to thoſe inhabitants.

The

The length of the longeſt day is obtained by reckoning the number of days between the two oppoſite days found as above, and their difference from 365 gives the length of their longeſt night.

PROBLEM XXVII.

To make uſe of the globe as a tellurian, or that kind of orrery which is chiefly intended to illuſtrate the phænomena that ariſe from the annual and diurnal motions of the earth.

Deſcribe a circle with chalk upon the floor, as large as the room will admit of, ſo that the globe may be moved round upon it; divide this circle into twelve parts, and mark them with the characters of the twelve ſigns, as they are engraved upon the broad paper circle; placing ♋ at the north, ♑ at the ſouth, ♈ in the eaſt, and ♎ in the weſt: the mariner's compaſs under the globe will direct the ſituation of theſe points, if the variation of the magnetic needle be attended to.

Note, At London the variation is between 23 and 24 degrees from the north weſtward.

Elevate the north pole of the globe, ſo that 66½ degrees on the ſtrong braſs meridian may coincide with the ſurface of the broad paper circle, and this circle will then repreſent the plane of

of the ECLIPTIC, or a plane coinciding with the earth's orbit.

Set a ſmall table, or a ſtool, over the center of the chalked circle, to repreſent the ſun, and place the terreſtrial globe upon it's circumference over the point marked ♑, with the north pole facing the imaginary ſun, and the north end of the needle pointing to the variation; and the globe will be in the poſition of the earth with reſpect to the ſun at the time of the ſummer ſolſtice, about the 21ſt of June; and the earth's axis, by this rectification of the globe, is inclined to the plane of the large chalked circle, as well as to the plane of the broad paper circle, in an angle of 66½ degrees; a line, or ſtring, paſſing from the center of the imaginary ſun to that of the globe, will repreſent a central ſolar ray connecting the centers of the earth and ſun: this ray will fall upon the firſt point of Cancer, and deſcribe that circle, ſhewing it to be the ſun's place upon the terreſtrial ecliptic, which is the ſame as if the ſun's place, by extending the ſtring, was referred to the oppoſite ſide of the chalked circle, here repreſenting the earth's path in the heavens.

If we conceive a plane to paſs through the center of the globe, and the ſun's center, it will alſo paſs through the points of Cancer and Capricorn, in the terreſtrial and celeſtial ecliptic; the central ſolar ray, in this poſition of the earth,

earth, is alſo in that plane; this can never happen but at the times of the ſolſtice.

If another plane be conceived to paſs through the center of the globe at right angles to the central ſolar ray, it will divide the globe into two hemiſpheres; that next the center of the chalked circle will repreſent the earth's illuminated diſc, the contrary ſide of the ſame plane will at the ſame time ſhew the obſcure hemiſphere.

The reader may realize this ſecond plane by cutting away a ſemicircle from a ſheet of card paſte-board, with a radius of about $1\frac{1}{2}$ tenth of an inch greater than that of the globe itſelf.*

If this plane be applied to $66\frac{1}{2}$ degrees upon the ſtrong braſs meridian, it will be in the pole of the ecliptic; and in every ſituation of the globe round the circumference of the chalked circle, it will afford a lively and laſting idea of the various phænomena ariſing from the paralleliſm of the earth's axis, and in particular the daily change of the ſun's declination, and the parallels thereby deſcribed.

Let the globe be removed from ♑ to ♒, and the needle pointing to the variation as before, will preſerve the paralleliſm of the earth's axis; then it will be plain, that the ſtring, or central ſolar ray, will fall upon the firſt point of Leo, ſix ſigns diſtant from, but oppoſite to the ſign ♒, upon

* Or he may have a plane made of wood for this purpoſe.

upon which the globe ſtands; the central ſolar ray will now deſcribe the 20th parallel of north declination, which will be about the 23d of July.

If the globe be moved in this manner from point to point round the circumference of the chalked circle, and care be taken at every removal that the north end of the magnetic needle, when ſettled, points to the degree of the variation, the north pole of the globe will be obſerved to recede from the line connecting the centers of the earth and ſun, until the globe is placed upon the point Cancer; after which, it will at every removal tend more and more towards the ſaid line, till it comes to Capricorn again.

PROBLEM XXVIII.

To rectify either globe to the latitude and horizon of any place.

If the place be in north latitude, raiſe the north pole; if in ſouth latitude, raiſe the ſouth pole, until the degree of the given latitude, reckoned on the ſtrong braſs meridian under the elevated pole, cuts the plane of the broad paper circle; then this circle will repreſent the horizon of that place.

PROBLEM XXIX.

To rectify for the ſun's place.

After the former rectification, bring the degrees of the ſun's place in the ecliptic line upon the globe to the ſtrong braſs meridian, and ſet the horary index to that XIIth hour upon the equator which is moſt elevated.

Or, if the ſun's place is to be retained, to anſwer various concluſions, bring the graduated edge of the moveable meridian to the degree of the ſun's place in the ecliptic, and ſlide the wire which croſſes the center of the artificial horizon thereto; then bring it's center, which is the interſection of the aforeſaid wire, and graduated edge of the moveable meridian, under the ſtrong braſs meridian as before, and ſet the horary index to that XII on the equator which is moſt elevated.

PROBLEM XXX.

To rectify for the zenith of any place.

After the firſt rectification, ſcrew the nut of the quadrant of altitude ſo many degrees from the equator, reckoned on the ſtrong braſs meridian towards the elevated pole, as that pole is raiſed above the plane of the broad paper circle, and that point will repreſent the zenith of the place.

Note,

Note, The zenith and nadir are the poles of the horizon, the former being a point directly over our heads, and the latter, one directly under our feet.

If when the globe is in this ſtate, we look on the oppoſite ſide, the plane of the horizon will cut the ſtrong braſs meridian at the complement of the latitude, which is alſo the elevation of the equator above the horizon.

Of the Solution of some Problems, in which the broad Paper Circle is considered as the rational Horizon.

PROBLEM XXXI.

To ſhew, at one view upon the terreſtrial globe, for any given place, the ſun's meridian altitude, his amplitude, or point of the compaſs, on which he riſes and ſets every day in the year.

Rectify the globe to the latitude of the given place, bring that place to the ſtrong braſs meridian, and ſet the horary index to XII; ſcrew the quadrant of altitude to the zenith of the horizon, and bring it to the braſs meridian.

You will then at one view ſee the ſun's meridian altitude on every degree of the ſun's declination for the whole year, cut by the graduated edge of the quadrant of altitude, on the dotted parallels.

These

These dotted parallels at the same instant also cut the edge of the broad paper circle, now representing the horizon, in the point of the compass, or amplitude, on which the sun is seen to rise on the east, or to set on the west side of the horizon, for every degree of declination throughout the year.

If you trace any of those parallels to the ecliptic line, you have the sun's place when he is upon that declination, and thence the day and month upon the horizon.

Also, the knowledge of the sun's place in the ecliptic line, shews the sun's declination for that time amongst the dotted parallels.

PROBLEM XXXII.

To shew at one view upon the terrestrial globe the length of the days and nights at any particular place, for all times of the year.

Rectify the globe to the latitude of the place, and the broad paper circle will represent the horizon; and the upper part of the dotted parallels of declination, which are here also parallels of latitude, will represent the diurnal arches.

Whence we may obtain the number of hours each of them contains, which is the solution of the problem. To illustrate this,

Elevate the globe to the position of a right sphere, and you will, with one glance of the eye, see

ſee that all the dotted parallels of declination, as well as the equator itſelf, are cut by the horizon into two equal parts.

Therefore the inhabitants on the equinoctial line have their days and nights twelve hours long; that is, the ſun is never more, nor ever leſs than twelve hours above their horizon, during his apparent paſſage from the tropic of Cancer to the tropic of Capricorn, and thence to Cancer again.

All the fixed ſtars have the ſame apparent motion to the equatorial inhabitants; that is, they riſe and ſet, continue above, and are depreſſed below the horizon of any place upon the equator, exactly twelve hours.

Raiſe the north pole of the globe a few degrees of latitude at a time, and you will ſee the diurnal arches increaſe in length, until the pole is elevated to 66½ degrees above the horizon; then the parallel of the ſun's greateſt declination will be as far from the equator as the place itſelf is from the pole; and this parallel is the tropic of Cancer, which will juſt touch the horizon in the north point.

And on the contrary, we may obſerve that the ſouthern parallels of declination continually ſhorten, as the northern ones lengthen, until they come to the tropic of Capricorn.

Rectify the globe to the latitude of London, 51½ degrees north; when the ſun is in the tropic

of Cancer, the day is about $16\frac{1}{2}$ hours; as he recedes from thence, the days ſhorten, as the length of the diurnal arches of the parallels ſhorten, until the ſun comes to Capricorn, and then the days are at the ſhorteſt, being of the ſame length with the nights when the ſun was in Cancer, viz. about $7\frac{1}{2}$ hours.

Rectify the globe to the altitude of the northern polar circle, and you will find, when the ſun is in Cancer, he touches the horizon on that day without ſetting, being completely twenty-four hours above the horizon; and when he is in Capricorn, he once appears in the horizon, but does not riſe for the ſpace of twenty-four hours; when he is upon any other parallel of declination, the days are longer or ſhorter, as that parallel is nearer to, or farther from the equator.

Elevate the globe to the latitude of 80 degrees north, at which time let the ſun's declination be 10 degrees north, he then apparently ſeems to turn round above the horizon without ſetting, and never ſets from this point to Cancer, until in his return, after he has again paſſed this parallel of declination.

In the ſame manner, when his declination is 10 degrees ſouth, he is juſt ſeen at noon in the horizon, and diſappears from that time in his ſoutherly motion, till his return to the ſame point.

Elevate the north pole to 90 degrees, or in the zenith, then the globe will be in the position of a parallel ſphere, and the equinoctial line will coincide with the plane of the horizon; conſequently all the northern parallels are above, and all the ſouthern parallels below the horizon; therefore, the polar inhabitants, if any there be, have but one day and one night throughout the year; their day, when the ſun is in his northern, and their night, when he is in his ſouthern declination.

PROBLEM XXXIII.

To find the angle of poſition of places.

The angle of poſition is that formed between the meridian of one of the places, and a great circle paſſing through the other place.

Rectify the globe to the latitude and zenith of one of the places, bring that place to the ſtrong braſs meridian, ſet the graduated edge of the quadrant to the other place, and the number of degrees contained between it and the ſtrong braſs meridian, is the meaſure of the angle ſought. Thus,

The angle of poſition between the meridian of Cape Clear, in Ireland, and St. Auguſtine, in Florida, is about 82 degrees north weſterly; but the angle of poſition between St. Auguſtine and

Cape Clear, is only about 46 degrees north eaſterly.

Hence it is plain, that the line of poſition, or azimuth, is not the ſame from either place to the other, as the romb lines are.

PROBLEM XXXIV.

To find the bearing of one place from another.

The bearing of one ſea-port from another is determined by a kind of ſpiral, called a romb-line paſſing from one to the other, ſo as to make equal angles with all the meridians it paſſeth by; therefore, if both places are ſituated on the ſame parallel of latitude, their bearing is either eaſt or weſt from each other; if they are upon the ſame meridian, they bear north and ſouth from one another; if they lie upon a romb-line, their bearing is the ſame with it; if they do not, obſerve to which romb-line the two places are neareſt parallel, and that will ſhew the bearing ſought.

Example. Thus the bearing of the Lizard point from the iſland of Bermudas, is nearly E. N. E.; and that of Bermudas from the Lizard is W. S. W. both nearly upon the ſame romb-line, but in contrary directions.

Or

OF THE SOLUTION OF PROBLEMS, BY EXPOSING THE GLOBES TO THE SUN'S RAYS.

In the year 1679, J. Moxon publiſhed a treatiſe on what he called "THE ENGLISH GLOBE; being (ſays he) a ſtabil and immobil one, performing what the ordinary globes do, and much more; invented and deſcribed by the Right Hon. the Earl of Caſtlemaine." This globe was deſigned to perform, by being merely expoſed to the ſun's rays, all thoſe problems which in the uſual way are ſolved by the adventitious aid of brazen meridians, hour indexes, &c.

My father thought that this method might be uſeful, to ground more deeply in the young pupil's mind, thoſe principles which the globes are intended to explain; and by giving him a different view of the ſubject, improve and ſtrengthen his mind; he therefore inſerted on his globes ſome lines, for the purpoſe of ſolving a few problems in Lord Caſtlemaine's manner.

It appears to me, from a copy of Moxon's publication, which is in my poſſeſſion, that the Earl of Caſtlemaine projects a new edition of his works, as the copy contains a great number of corrections, many alterations, and ſome additions. It is not very improbable, that at ſome future day I may re-publiſh this curious work, and adapt a ſmall globe for the ſolution of the problems.

The meridians on our new terreftrial globes being fecondaries to the equator, are alfo hour circles, and are marked as fuch with Roman figures, under the equator, and at the polar circles. But there is a difference in the figures placed to the fame hour circle; if it cuts the IIId hour upon the polar circles, it will cut the IXth hour upon the equator, which is fix hours later, and fo of all the reft.

Through the great Pacific fea, and the interfection of Libra, is drawn a broad meridian from pole to pole; it paffes through the XIIth hour upon the equator, and the VIth hour upon each of the polar circles; this hour circle is graduated into degrees and parts, and numbered from the equator towards either pole.

There is another broad meridian paffing through the Pacific fea, at the IXth hour upon the equator, and the IIId hour upon each polar circle; this contains only one quadrant, or 90 degrees; the numbers annexed to it begin at the northern polar circle, and end at the tropic of Capricorn.

Here we muft likewife obferve, there are 23 concentric circles drawn upon the terreftrial globe within the northern and fouthern polar circles, which for the future we fhall call polar parallels; they are placed at the diftance of one degree from each other, and reprefent the parallels of the fun's declination, but in a different manner

manner from the 47 parallels betwen the tropics.

The following problems require the globe to be placed upon a plane that is level, or truly horizontal, which is eafily attained, if the floor, pavement, gravel-walk in the garden, &c. fhould not happen to be horizontal.

A flat feafoned board, or any box which is about two feet broad, or two feet fquare, if the top be perfectly flat, will anfwer the purpofe; the upper furface of either may be fet truly horizontal, by the help of a pocket fpirit level, or plumb rule, if you raife or deprefs this or that fide by a wedge or two, as the fpirit level fhall direct; if you have a meridian line drawn on the place over which you fubftitute this horizontal plane, it may be readily transferred from thence to the furface juft levelled; this being done, we are prepared for the folution of the following problems.

It will be neceffary to define a term we are obliged to make ufe of in the folution of thefe problems, namely, the SHADE OF EXTUBERANCY: by this is meant that fhade which is caufed by the fphericity of the globe, and anfwers to what we have heretofore named the terminator, defining the boundaries of the illuminated and obfcure parts of the globe; this circle was, in the folution of fome of the foregoing problems, re-

presented by the broad paper circle, but is here realized by the rays of the sun.

PROBLEM XXXV.

To observe the sun's altitude (by the terrestrial globe) when he shines bright, or when he can but just be discerned through a cloud.

Elevate the north pole of the globe to 66$\frac{1}{2}$ degrees; bring that meridian, or hour circle, which passes through the IXth hour upon the equator, under the graduated side of the strong brass meridian; the globe being now set upon the horizontal plane, turn it about thereon, frame and all, that the shadow of the strong brass meridian may fall directly under itself; or in other words, that the shade of it's graduated face may fall exactly upon the aforesaid hour circle; at that instant the shade of extuberancy will touch the true degree of the sun's altitude upon that meridian, which passes through the IXth hour upon the equator, reckoned from the polar circle, the most elevated part of which will then be in the zenith of the place where this operation is performed, and is the same whether it should happen to be either in north or south latitude.

Thus we may, in an easy and natural manner, obtain the altitude of the sun, at any time of the day,

day, by the terreſtrial globe; for it is very plain, when the ſun riſes, he bruſhes the zenith and nadir of the globe by his rays; and as he always illuminates half of it, (or a few minutes more, as his globe is conſiderably larger that that of the earth) therefore when the ſun is riſen a degree higher, he muſt neceſſarily illuminate a degree beyond the zenith, and ſo on proportionably from time to time.

But as the illuminated part is ſomewhat more than half, deduct 13 minutes from the ſhade of extuberancy, and you have the ſun's altitude with tolerable exactneſs.

If you have any doubt how far the ſhade of extuberancy reaches, hold a pin, or your finger, on the globe, between the ſun and point in diſpute, and where the ſhade of either is loſt, will be the point ſought.

When the ſun does not ſhine bright enough to caſt a ſhadow.

Turn the meridian of the globe towards the ſun, as before, or direct it ſo that it may lie in the ſame plane with it, which may be done if you have but the leaſt glimpſe of the ſun through a cloud; hold a ſtring in both hands, it having firſt been put between the ſtrong braſs meridian and the globe; ſtretch it at right angles to the meridian, and apply your face near to the globe, moving

moving your eye lower and lower, till you can but juſt ſee the ſun; then bring the ſtring held as before to this point upon the globe, that it may juſt obſcure the ſun from your ſight, and the degree on the aforeſaid hour circle, which the ſtring then lies upon, will be the ſun's altitude required, for his rays would ſhew the ſame point if he ſhone out bright.

Note, The moon's altitude may be obſerved by either of theſe methods, and the altitude of any ſtar by the laſt of them.

PROBLEM XXXVI.

To place the terreſtrial globe in the ſun's rays, that it may repreſent the natural poſition of the earth, either by a meridian line, or without it.

If you have a meridian line, ſet the north and ſouth points of the broad paper circle directly over it, the north pole of the globe being elevated to the latitude of the place, and ſtanding upon a level plane, bring the place you are in under the graduated ſide of the ſtrong braſs meridian, then the poles and parallel circles upon the globe will, without ſenſible error, correſpond with thoſe in the heavens, and each point, kingdom, and ſtate, will be turned towards the real one which it repreſents.

If

If you have no meridian line, then the day of the month being known, find the ſun's declination as before inſtructed, which will direct you to the parallel of the day, amongſt the polar parallels, reckoned from either pole towards the polar circle ; which you are to remember.

Set the globe upon your horizontal planen the ſun-ſhine, and put it nearly north and ſouth by the mariner's compaſs, it being firſt elevated to the latitude of the place, and the place itſelf brought under the graduated ſide of the ſtrong braſs meridian; then move the frame and globe together, till the ſhade of extuberancy, or term of illumination, juſt touches the polar parallel for the day, and the globe will be ſettled as before; and if accurately performed, the variation of the magnetic needle will be ſhewn by the degree to which it points in the compaſs box.

And here obſerve, if the parallel for the day ſhould not happen to fall on any one of thoſe drawn upon the globe, you are to eſtimate a proportionable part between them, and reckon that the parallel of the day. If we had drawn more, the globe would have been confuſed.

The reaſon of this operation is, that as the ſun illuminates half the globe, the ſhade of extuberancy will conſtantly be 90 degrees from the point wherein the ſun is vertical.

If the ſun be in the equator, the ſhade and illumination muſt terminate in the poles of the world; and when he is in any other diurnal parallel, the terms of illumination muſt fall ſhort of, or go beyond either pole, as many degrees as the parallel which the ſun deſcribes that day is diſtant from the equator; therefore, when the ſhade of extuberancy touches the polar parallel for the day, the artificial globe will be in the ſame poſition, with reſpect to the ſun, as the earth really is, and will be illuminated in the ſame manner.

PROBLEM XXXVII.

To find naturally the ſun's declination, diurnal parallel, and his place thereon.

The globe being ſet upon an horizontal plane, and adjuſted by a meridian line or otherwiſe, obſerve upon which, or between which polar parallel the term of illumination falls; it's diſtance from the pole is the degree of the ſun's declination; reckon this diſtance from the equator among the larger parallels, and you have the parallel which the ſun deſcribes that day; upon which if you move a card, cut in the form of a double ſquare, until it's ſhadow falls under itſelf, you will obtain the very place upon that parallel over which the ſun is vertical at any hour of that day, if you ſet the place you

are

are in under the graduated ſide of the ſtrong braſs meridian.

Note, The moon's declination, diurnal parallel, and place, may be found in the ſame manner. Likewiſe, when the ſun does not ſhine bright, his declination, &c. may be found by an application in the manner of problem 35.

PROBLEM XXXVIII.

To find the ſun's azimuth naturally.

If a great circle, at right angles to the horizon, paſſes through the zenith and nadir, and alſo through the ſun's center, it's diſtance from the meridian in the morning or evening of any day, reckoned upon the degrees on the inner edge of the broad paper circle, will give the azimuth required.

METHOD I.

Elevate either pole to the poſition of a parallel ſphere, by bringing the north pole in north latitude, and the ſouth pole in ſouth latitude, into the zenith of the broad paper circle, having firſt placed the globe upon your meridian line, or by the other method before preſcribed; hold up a plumb line, ſo that it may paſs freely near the outward edge of the broad paper circle,

and move it ſo that the ſhadow of the ſtring may fall upon the elevated pole ; then caſt your eye immediately to it's ſhadow on the broad paper circle, and the degree it there falls upon is the ſun's azimuth at that time, which may be reckoned from either the ſouth or north points of the horizon.

METHOD II.

If you have only a glimpſe, or faint ſight of the ſun, the globe being adjuſted as before, ſtand on the ſhady ſide, and hold the plumb line on that ſide alſo, and move it till it cuts the ſun's center, and the elevated pole at the ſame time; then caſt your eye towards the broad paper circle, and the degree it there cuts is the ſun's azimuth, which muſt be reckoned from the oppoſite cardinal point.

PROBLEM XXXIX.

To ſhew that in ſome places of the earth's ſurface, the ſun will be twice on the ſame azimuth in the morning, twice on the ſame azimuth in the afternoon: or in other words,

When the declination of the ſun exceeds the latitude of any place, on either ſide of the equator, the ſun will be on the ſame azimuth twice in the morning, and twice in the afternoon.

Thus,

Thus, ſuppoſe the globe rectified to the latitude of Antigua, which is about 17 deg. of north latitude, and the ſun to be in the beginning of Cancer, or to have the greateſt north declination; ſet the quadrant of altitude to the 21ſt degree north of the eaſt in the horizon, and turn the globe upon it's axis, the ſun's center will be on that azimuth at 6 h. 30 min. and alſo at 10 h. 30 min. in the morning. At 8 h. 30 min. the ſun will be as it were ſtationary, with reſpect to it's azimuth, for ſome time; as it will appear by placing the quadrant of altitude to the 17th degree north of the eaſt in the horizon. If the quadrant be ſet to the ſame degrees north of the weſt, the ſun's center will croſs it twice as it approaches the horizon in the afternoon.

This appearance will happen more or leſs to all places ſituated in the torrid zone, whenever the ſun's declination exceeds their latitude; and from hence we may infer, that the ſhadow of a dial, whoſe gnomon is erected perpendicular to an horizontal plane, muſt neceſſarily go back ſeveral degrees on the ſame day.

But as this can only happen within the torrid zone, and as Jeruſalem lies about 8 degrees to the north of the tropic of Cancer, the retroceſſion of the ſhadow on the dial of Ahaz, at Jeruſalem, was, in the ſtricteſt ſignification of the word, miraculous.

PROBLEM

PROBLEM XL.

To obſerve the hour of the day in the moſt natural manner, when the terreſtrial globe is properly placed in the ſun-ſhine.

There are many ways to perform this operation with reſpect to the hour, three of which are here inſerted, being general to all the inhabitants of the earth; a fourth is added, peculiar to thoſe of London, which will anſwer, without ſenſible error, at any place not exceeding the diſtance of 60 miles from this capital.

1ſt, By a natural ſtile.

Having rectified the globe as before directed, and placed it upon an horizontal plane over your meridian line, or by the other method, hold a long pin upon the illuminated pole, in the direction of the polar axis, and it's ſhadow will ſhew the hour of the day amongſt the polar parallels.

The axis of the globe being the common ſection of the hour circles, is in the plane of each; and as we ſuppoſe the globe to be properly adjuſted, they will correſpond with thoſe in the heavens; therefore, the ſhade of a pin, which is the axis continued, muſt fall upon the true hour circle.

2ndly,

2ndly, By an artificial ſtile.

Tye a ſmall ſtring, with a nooſe, round the elevated pole, ſtretch it's other end beyond the globe, and move it ſo that the ſhadow of the ſtring may fall upon the depreſſed axis; at that inſtant it's ſhadow upon the equator will give the ſolar hour to a minute.

But remember, that either the autumnal or vernal equinoctial colure muſt firſt be placed under the graduated ſide of the ſtrong braſs meridian, before you obſerve the hour, each of theſe being marked upon the equator with the hour XII.

The ſtring in this laſt caſe being moved into the plane of the ſun, correſponds with the true hour circle, and conſequently gives the true hour.

3dly, Without any ſtile at all.

Every thing being rectified as before, look where the ſhade of extuberancy cuts the equator, the colure being under the graduated ſide of the ſtrong braſs meridian, and you obtain the hour in two places upon the equator, one of them going before, and the other following the ſun.

Note, If this ſhade be dubious, apply a pin, or your finger, as before directed.

The reafon is, that the fhade of extuberancy being a great circle, cuts the equator in half, and the fun, in whatfoever parallel of declination he may happen to be, is always in the pole of the fhade; confequently the confines of light and fhade will fhew the true hour of the day.

4thly, Peculiar to the inhabitants of London, and any place within the diftance of fixty miles from it.

The globe being every way adjufted as before, and London brought under the graduated fide of the ftrong brafs meridian, hold up a plumb line, fo that it's fhadow may fall upon the zenith point, (which in this cafe is London itfelf) and the fhadow of the ftring will cut the parallel of the day upon that point to which the fun is then vertical, and that hour circle upon which this interfection falls, is the hour of the day; and as the meridians are drawn within the tropics, at 20 minutes diftance from each other, the point cut by the interfection of the ftring upon the parallel of the day, being fo near the equator, may, by a glance of the obferver's eye, be referred thereto, and the true time obtained to a minute.

The plumb line thus moved, is the azimuth; which, by cutting the parallel of the day, gives the

the ſun's place, and conſequently the hour circle which interſects it.

From this laſt operation reſults a corollary, that gives a ſecond way of rectifying the globe to the ſun's rays.

If the azimuth and ſhade of the illuminated axis agree in the hour when the globe is rectified, then making them thus to agree, muſt rectify the globe.

COROLLARY.

Another method to rectify the globe to the ſun's rays.

Move the globe, till the ſhadow of the plumb line, which paſſes through the zenith, cuts the ſame hour on the parallel of the day, that the ſhade of the pin, held in the direction of the axis, falls upon, amongſt the polar parallels, and the globe is rectified.

The reaſon is, that the ſhadow of the axis repreſents an hour circle; and by it's agreement in the ſame hour, which the ſhadow of the azimuth ſtring points out, by it's interſection on the parallel of the day, it ſhews the ſun to be in the plane of the ſaid parallel; which can never happen in the morning on the eaſtern ſide of the globe, nor in the evening on the weſtern ſide of it, but when the globe is rectified.

This rectification of the globe is only placing it in ſuch a manner, that the principal great

circles and points may concur and fall in with thofe of the heavens.

The many advantages arifing from thefe problems, relating to the placing of the globe in the fun's rays, the tutor will eafily difcern, and readily extend to his own, as well as to the benefit of his pupil.

THE GENERAL PRINCIPLES OF DIALLING ILLUSTRATED BY THE TERRESTRIAL GLOBE.

THE art of dialling is of very ancient origin, and was in former times cultivated by all who had any pretenfions to fcience; and before the invention of clocks and watches, it was of the higheft importance, and is even now ufed to correct and regulate them.

It teaches us, by means of the fun's rays, to divide time into equal parts, and to reprefent on any given furface the different circles into which, for convenience, we fuppofe the heavens to be divided, but principally the hour circles.

The hours are marked upon a plane, and pointed out by the interpofition of a body, which receiving

receiving the light of the ſun, caſts a ſhadow upon the plane. This body is called the axis, when it is parallel to the axis of the world. It is called the ſtyle, when it is ſo placed that only the end of it coincides with the axis of the earth; in this caſe, it is only this point which marks the hours.

Among the various pleaſing and profitable amuſements which ariſe from the uſe of globes, that of dialling is not the leaſt. By it the pupil will gain ſatisfactory ideas of the principles on which this branch of ſcience is founded; and it will reward, with abundance of pleaſure, thoſe that chuſe to exercиſe themſelves in the practice of it.

If we imagine the hour circles of any place, as London, to be drawn upon the globe of the earth, and ſuppoſe this globe to be tranſparent, and to revolve round a real axis, which is opake, and caſts a ſhadow; it is evident, that whenever the plane of any hour ſemicircle points at the ſun, the ſhadow of the axis will fall upon the oppoſite ſemicircle.*

Let a P C p, fig. 1, plate XII. repreſent a tranſparent globe; a b c d e f g the hour ſemicircles; it is clear, that if the ſemicircle P a p points at the ſun, the ſhadow of the axis will fall upon the oppoſite ſemicircle.

 If

* Long's Aſtronomy, vol. 1, page 82.

If we imagine any plane to paſs through the center of this tranſparent globe, the ſhadow of half the axis will always fall upon one ſide or the other of this interſecting plane.

Thus let A B C D be the plane of the horizon of London; ſo long as the ſun is above the horizon, the ſhadow of the upper half of the axis will fall ſomewhere upon the upper ſide of the plane A B C D; when the ſun is below the horizon of London, then the ſhadow of the lower half of the axis E falls upon the lower ſide of the plane.

When the plane of any hour ſemicircle points at the ſun, the ſhadow of the axis marks the reſpective hour line upon the interſecting plane. The hour line is therefore a line drawn from the center of the interſecting plane, to that point where this plane is cut by the ſemicircle oppoſite to the hour ſemicircle.

Thus let A B C D, fig. 1, plate XII. the horizon of London, be the interſecting plane; when the meridian of London points at the ſun, as in the preſent figure, the ſhadow of the half axis P E falls upon the line E B, which is drawn from E, the center of the horizon, to the point where the horizon is cut by the oppoſite ſemicircle; therefore, E B is the line for the hour of twelve at noon.

By the ſame method the reſt of the hour lines are found, by drawing for every hour a line from the

the center of the interſecting plane, to that ſemicircle which is oppoſite to the hour ſemicircle.

Thus fig. 2, plate XII. ſhews the hour lines drawn upon the plane of the horizon of London, with only ſo many hours as are neceſſary; that is, thoſe hours, during which the ſun is above the horizon of London, on the longeſt day in ſummer.

If, when the hour lines are thus found, the ſemicircles be taken away, as the ſcaffolding is when the houſe is built, what remains, as in fig. 2, will be an HORIZONTAL DIAL for London.

If, inſtead of twelve hour circles as above deſcribed, we take twice that number, we may by the points, where the interſecting plane is cut by them, find the lines for every half hour; if we take four times the number of hour circles, we may find the lines for every quarter of an hour, and ſo on progreſſively.

We have hitherto conſidered the horizon of London as the interſecting plane, by which is ſeen the method of making an horizontal dial. If we take any other plane for the interſecting plane, and find the points where the hour ſemicircles paſs through it, and draw lines from the center of the plane to thoſe points, we ſhall have the hour lines for that plane.

Fig. 3, plate XII. ſhews how the hour lines are found upon a ſouth plane, perpendicular to

the horizon. Fig. 4, ſhews a ſouth dial, with it's hour lines, without the ſemicircle, by means whereof they are found.

The GNOMON of every ſun-dial repreſents the axis of the earth, and is therefore always placed parallel to it, whether it be a wire, as in the figure before us, or the edge of a braſs plate, as in a common horizontal dial.

The whole earth, as to it's bulk, is but a POINT, if compared to it's diſtance from the ſun; therefore, if a ſmall ſphere of glaſs be placed on any part of the earth's ſurface, ſo that it's axis be parallel to the axis of the earth, and the ſphere have ſuch lines upon it, and ſuch planes within it, as above deſcribed, it will ſhew the hour of the day as truly as if it were placed at the center of the earth, and the ſhell of the earth were as tranſparent as glaſs.

A wire ſphere, with a thin flat plate of braſs within it, is often made uſe of to explain the principles of dialling.

From what has been ſaid, it is clear that dialling depends on finding where the ſhadow of a ſtrait wire, parallel to the axis of the earth, will fall upon a given plane, every hour, half-hour, &c. the hour lines being found as above deſcribed, which we ſhall proceed to exemplify by the globe.

Every dial plane (that is, the plane ſurface on which a dial is drawn) repreſents the plane of a

great

great circle, which circle is an HORIZON to ſome country or other.

The center of the dial repreſents the center of the earth; and the gnomon which caſts the ſhade repreſents the axis, and ought to point directly to the poles of the equator.

The plane upon which dials are delineated may be either, 1. parallel to the horizon; 2. perpendicular to the horizon; or, 3. cutting it at oblique angles.

PROBLEM XLI.

To conſtruct an horizontal dial for any given latitude, by means of the terreſtrial globe.

Elevate the globe to the latitude of the place; then bring the firſt meridian under the graduated edge of the ſtrong brazen one, which will then be over the hour XII, or the equator. As our globes have meridians drawn through every 15 degrees of the equator, theſe meridians will repreſent the true circles of the ſphere, and will interſect the horizon of the globe, in certain points on each ſide of the meridian. The diſtance of theſe points from the meridian, muſt be carefully noted down upon a piece of paper, as will be ſeen in the example. The pupil need not, however, take out into his table the diſtances further than from XII to VI, which is juſt 90 degrees; for the diſtances of XI, X, IX, VIII, VII, VI, in the forenoon, are the ſame from XII

as the diſtances of I, II, III, IV, V, VI, in the afternoon; and theſe hour lines continued through the center will give the oppoſite hour lines on the other half of the dial.

No more hour lines need be drawn than what anſwer to the ſun's continuance above the horizon, on the longeſt day of the year, in the given latitude.

Example. Suppoſe the given place to be London, whoſe latitude is 51 deg. 30 min. north.

Elevate the north pole of the globe to $51\frac{1}{2}$ degrees above the horizon; then will the axis of the globe have the ſame elevation above the broad paper circle, as the gnomon of the dial is to have above the plane thereof.

Turn the globe, till the firſt meridian (which on Engliſh globes paſſes through London) is under the graduated ſide of the ſtrong brazen meridian; then obſerve and note the points where the hour circles interſect the horizon; and as on our globes the inner graduated circle, on the broad paper circle, begins from the two fixes, or eaſt and weſt, we ſhall begin from thence, calling

the hour - -	VI	0°	0
we ſhall find the other hours interſecting the horizon at the following degrees:	V	18°	54
	IV	36	24
	III	51	57
	II	65	41
	I	78	9

which

which are the refpective diftances of the above hours from VI upon the plane of the horizon.

To transfer thefe, and the reft of the hours, upon an horizontal plane, draw the parallel right lines a c and b d, fig. 5, plate XII. upon that plane, as far from each other as is equal to the intended thicknefs of the gnomon of the dial, and the fpace included between them will be the meridian, or twelve o'clock line upon the dial; crofs this meridian at right angles by the line g h, which will be the fix o'clock line; then fetting one foot of your compaffes in the interfection a, defcribe the quadrant g e with any convenient radius, or opening of the compaffes; after this, fet one foot of the compaffes in the interfection b, as a center, and with the fame radius defcribe the quadrant f h; then divide each quadrant into 90 equal parts, or degrees, as in the figure.

Becaufe the hour lines are lefs diftant from each other about noon, than in any other part of the dial, it is beft to have the centers of the quadrants at fome diftance from the center of the dial plane, in order to enlarge the hour diftances near XII; thus the center of the plane is at A, but the center of the quadrants is at a and b.

Lay a rule over 78° 9′, and the center b, and draw there the hour line of I. Through b, and 65 41, gives the hour line of II. Through b, and 51 57, that of III. Through the fame center, and 36 24, we obtain the hour line of IV. And

And through it, and 18 54, that of V. And becaufe the fun rifes about four in the morning, continue the hour lines of IV and V in the afternoon, through the center b to the oppofite fide of the dial.

Now lay a rule fucceffively to the center a of the quadrant e g, and the like elevations or degrees of that quadrant, 78,9, 65,41, 51,57, 36,24, 18,54, which will give the forenoon hours of XI, X, IX, VIII, and VII; and becaufe the fun does not fet before VIII in the evening on the longeft days, continue the hour lines of VII and VIII in the afternoon, and all the hour lines will be finifhed on this dial.

Laftly, through 51 ½ degrees on either quadrant, and from it's center, draw the right line a g for the axis of the gnomon a g i, and from g let fall the perpendicular g i upon the meridian line a i, and there will be a triangle made, whofe fides are a g, g i, and i a; if a plate fimilar to this triangle be made as thick as the diftance between the lines a c and b d, and be fet upright between them, touching at a and b, the line a g will, when it is truly fet, be parallel to the axis of the world, and will caft a fhadow on the hour of the day.

The trouble of dividing the two quadrants may be faved, by ufing a line of chords, which is always placed upon every fcale belonging to a cafe of inftruments.

PROBLEM XLII.

To delineate a direct ſouth dial for any given latitude, by the globe.

Let us ſuppoſe a ſouth dial for the latitude of London.

Elevate the pole to the co-latitude of your place, and proceed in all reſpects as above taught for the horizontal dial, from VI in the morning to VI in the afternoon, only the hours muſt be reverſed, as in fig. 3, plate XII.; and the hypothenuſe a g of the gnomon a g f, muſt make an angle with the dial plane to the co-latitude of the place.

As the ſun can ſhine no longer than from VI in the morning to VI in the evening, there is no occaſion for having more than twelve hours upon this dial.

In ſolving this problem, we have conſidered our vertical ſouth dial for the latitude of London, as an horizontal one for the complement of that latitude, or 38 deg. 30 min.; all direct vertical dials may be thus reduced to horizontal ones, in the ſame manner. The reaſon of this will be evident, if the globe be elevated to the latitude of London; for by fixing the quadrant of altitude to the zenith, and bringing it to interſect the horizon in the eaſt point, it will point out the plane of the propoſed dial.

This plane is at right angles to the meridian, and

and perpendicular to the horizon; and it is clear, from the bare inſpection of the globe thus elevated, that it's axis forms an angle with this plane, which is juſt the complement of that which it forms with the horizon, and is therefore juſt equal to the co-latitude of the place, and that therefore it is moſt ſimple to rectify the globe to that co-latitude.

The north vertical dial is the ſame with the ſouth, only the ſtyle muſt point upwards, and that many of the hours from it's direction can be of no uſe.

PROBLEM XLIII.

To make an erect dial, declining from the ſouth towards the eaſt or weſt.

Elevate the pole to the latitude of the place, and ſcrew the quadrant of altitude to the zenith.

Then if your dial declines towards the eaſt, (which we ſhall ſuppoſe in the preſent inſtance) count in the horizon the degrees of declination, from the eaſt point towards the north, and bring the lower end of the quadrant to coincide with that degree of declination at which the reckoning ends.

Then bring the firſt meridian under the graduated edge of the ſtrong brazen meridian, which ſtrong meridian will be the horary index.

Now turn the globe weſtward, and obſerve the degrees cut in the quadrant of altitude by the firſt

firſt meridian, while the hours XI, X, IX, &c. in the forenoon, paſs ſucceſſively under the brazen one; and the degrees thus cut on the quadrant by the firſt meridian, are the reſpective diſtances of the forenoon hours, from XII, on the plane of the quadrant.

For the afternoon hours, turn the quadrant of altitude round the zenith, until it comes to the degree in the horizon, oppoſite to that where it was placed before, namely, as far from the weſt towards the ſouth, and turn the globe eaſtward; and as the hours I, II, III, &c. paſs under the ſtrong brazen meridian, the firſt meridian will cut on the quadrant of altitude the number of degrees from the zenith, that each of the hours is from XII on the dial.

When the firſt meridian goes off the quadrant at the horizon, in the forenoon, the hour index will ſhew the time when the ſun comes upon this dial; and when it goes off the quadrant in the afternoon, it points to the time when the ſun leaves the dial.

Having thus found all the hour diſtances from XII, lay them down upon your dial plane, either by dividing a ſemicircle into two quadrants, or by the line of chords.

In all declining dials, the line on which the gnomon ſtands makes an angle with the twelve o'clock line, and falls among the forenoon hour lines, if the dial declines towards the eaſt; and among the afternoon hour lines, when the dial

declines towards the weſt; that is, to the left hand from the twelve o'clock line in the former caſe, and to the right hand from it in the latter.

To find the diſtance of this line from that of twelve.

This may be conſidered, 1. If the dial declines from the ſouth towards the eaſt, then count the degrees of that declination in the horizon, from the eaſt point towards the north, and bring the lower end of the quadrant to that degree of declination where the reckoning ends; then turn the globe, until the firſt meridian cuts the horizon in the like number of degrees, counted from the ſouth point towards the eaſt, and the quadrant and firſt meridian will croſs one another at right angles, and the number of degrees of the quadrant, which are intercepted between the firſt meridian and the zenith, is equal to the diſtance of this line from the twelve o'clock line.

The numbers of the firſt meridian, which are intercepted between the quadrant and the north pole, is equal to the elevation of the ſtyle above the plane of the dial.

The ſecond caſe is, when the dial declines weſtward from the ſouth.

Count the declination from the eaſt point of the horizon, towards the ſouth, and bring the quadrant of altitude to the degree in the horizon, at which the reckoning ends, both for finding the

the forenoon hours, and the diſtance of the ſubſtile, or gnomon line, from the meridian; and for the afternoon hours, bring the quadrant to the oppoſite degrees in the horizon, namely, as far from the weſt towards the north, and then proceed in all reſpects as before.

It is preſumed, that the foregoing inſtances will be ſufficient to illuſtrate the general principles of dialling, and to give the pupil a general idea of that pleaſing ſcience; for accurate and expeditious methods of conſtructing dials, we muſt refer him to treatiſes written expreſsly on that ſubject.

NAVIGATION

EXPLAINED BY THE

GLOBE.

NAVIGATION is the art of guiding a ſhip at ſea, from one place to another, in the ſafeſt and moſt convenient manner. In order to attain this, four things are particularly neceſſary:

1. To know the ſituation and diſtance of places.

2. To know at all times the points of the compaſs.

3. To know the line in which the ſhip is to be directed from one place to the other.

4. To know, in any part of the voyage, what point of the globe the ſhip is upon.

The knowledge of the diſtance and ſituation of places, between which a voyage is to be made, implies not only a general knowledge of geography, but of ſeveral other particulars, as the rocks, ſands, ſtreights, rivers, &c. near which we are to ſail; the bending out, or running in of the ſhores, the knowledge of the times that particular winds ſet in, the ſeaſons when ſtorms and hurricanes are to be expected, but eſpecially the tides; theſe and many other ſimilar circumſtances are to be learned from ſea charts, journals, &c. but chiefly by obſervation and experience.

The ſecond particular to be attained, is the knowledge at all times of the points of the compaſs, where the ſhip is. The ancients, to whom the polarity of the loadſtone was unknown, found in the day-time the eaſt or weſt, by the riſing or ſetting of the ſun; and at night, the north by the polar ſtar. We have the advantage of the mariner's compaſs, by which, at any time in the wide ocean, and the darkeſt night, we know where the north is, and conſequently the reſt of the points of the compaſs.

Indeed, before the invention of the mariner's compaſs, the voyages of the Europeans were principally confined to coaſting; but this fortunate diſcovery has enabled the mariner to explor

plore new ſeas, and diſcover new countries, which, without this valuable acquiſition, would probably have remained for ever unknown.

The third thing required to be known, is the line which a ſhip deſcribes upon the globe of the earth, in going from one place to another.

The ſhorteſt way from one place to another, is an arc of a great circle, drawn through the two places.

The moſt convenient way for a ſhip, is that by which we may ſail from one place to another, directing the ſhip all the while towards the ſame point of the compaſs.

A ſhip is guided by ſteering or directing her towards ſome points of the compaſs; the line wherein a ſhip is directed, is called the ſhip's courſe, which is named from the point towards which ſhe ſails.

Thus if a ſhip ſails towards the north-eaſt point, her courſe is ſaid to be N. E.

In long voyages, a ſhip's way may conſiſt of a great number of different courſes, as from A to B, from B to C, and from C to D, fig. 9, plate XII.; when we ſpeak of a ſhip's courſe, we conſider one of theſe at a time; t e ſeldomer the courſe is changed, the more eaſily the ſhip is directed.

If two places, A and Z, fig. 7, plate XII. lie under the same meridian, the courſe from the one to the other is due north or ſouth.

 Thus

Thus let A Z be part of a meridian; if A be ſouth of Z, the courſe from A to Z muſt be north, and the courſe from Z to A ſouth. This is evident from the nature of a meridian, that it marks upon the horizon the north and ſouth points, and that every point of any meridian is north or ſouth from every other point of it. From hence we may deduce the following corollary: that if a ſhip ſails due north or ſouth, ſhe will continue on the ſame meridian.

If two places lie under the equator, the courſe from one to the other is an arc of the equator, and is due eaſt or weſt. Thus let a z, fig. 7, be a part of the equator; if a be weſt from z, the courſe from a to z is eaſt, and the courſe from z to a is weſt: for ſince the equator marks the eaſt and weſt points upon the horizon, every point of the equator lies eaſt or weſt of every other point of it, as may be ſeen upon the globe, by placing it as for a right ſphere, and bringing a or z, or any of the intermediate points, to the zenith; when it will be evident, that if we are to go from one of theſe points a, to the other z, or to any point on the equator, we muſt continue our courſe due eaſt to arrive at a, or vice verſa. From hence we may deduce this conſequence, that if a ſhip under the equator ſails due eaſt or weſt, ſhe will continue under the equator.

In the two foregoing caſes, the courſe being

an

an arc of a great circle, (the meridian or equator) is the ſhorteſt and the moſt convenient way it can ſail.

IF TWO PLACES LIE UNDER THE SAME PARALLEL, the courſe from one to the other is due eaſt or weſt; this may be ſeen upon the globe, by the following method: bring any point of a parallel to the zenith, and ſtretch a thread over it, perpendicular to the meridian; the thread will then be a tangent to the parallel, and ſtand eaſt and weſt from the point of contact. Hence, if a ſhip ſails in any parallel, due eaſt or weſt, ſhe will continue in the ſame parallel. In this caſe, the moſt convenient courſe, though not the ſhorteſt, from one to the other, is to ſail due eaſt or weſt.

IF TWO PLACES LIE NEITHER UNDER THE EQUATOR, NOR ON THE SAME MERIDIAN, NOR IN THE SAME PARALLEL, the moſt convenient, though not the ſhorteſt, courſe from one to the other, is in a rhumb.

For if we ſhould in this caſe attempt to go the ſhorteſt way, in a great circle drawn through the two places, we muſt be perpetually changing our courſe. Thus fig. 8, whatever is the bearing of Z from A, the bearings of all the intermediate points, as B, C, D, E, &c. will be different from it, as well as different from each other, as may be eaſily ſeen upon the globe, by bringing the firſt point A to the zenith, and ob-

ſerving the bearing of Z from each of them. Thus ſuppoſe when the globe is rectified to the horizon of A, the bearing of Z from A be north-eaſt, and the angle of poſition of Z, with regard to A, be 45 degrees; if we bring B to the zenith, we ſhall have a different horizon, and the bearing and angle of poſition from Z to B will be different from the former; and ſo on of the other points C, D, E, they will each of them have a different horizon, and Z will have a different bearing and angle of poſition.

From hence we may draw this corollary, that when two places lie one from the other, towards a point not cardinal, if we ſail from one place towards the point of the other's bearing, we ſhall never arrive at the other place. Thus if Z lies north-eaſt from A, if we ſail from A towards the north-eaſt, we ſhall never arrive at Z.

A RHUMB upon the globe is a line drawn from a given place A, ſo as to cut all the meridians it paſſes through at equal angles; the rhumbs are denominated from the points of the compaſs, in a different manner from the winds. Thus, at ſea, the north-eaſt wind is that which blows from the north-eaſt point of the horizon, towards the ſhip in which we are; but we are ſaid to ſail upon the N. E. rhumb, when we go towards the north-eaſt.

The rhumb A B C D Z, fig. 8, plate XII, paſſing

paſſing through the meridians L M, N O, P Q, makes the angles L A B, N B C, P C D, equal; from whence it follows, that the direction of a rhumb is in every part of it towards the ſame point of the compaſs; thus from every point of a north-eaſt rhumb upon the globe, the direction is towards the north-eaſt, and that rhumb makes an angle of 45 deg. with every meridian it is drawn through.

Another property of the rhumbs is, that equal parts of the ſame rhumb are contained between parallels of equal diſtance of latitude; ſo that a ſhip continuing in the ſame rhumb, will run the ſame number of miles in ſailing from the parallel of 10 to the parallel of 30, as ſhe does in ſailing from the parallel of 30 to that of 50.

The fourth thing mentioned to be required in navigation, was, to know at any time what point of the globe a ſhip is upon. This depends upon four things; 1. the longitude; 2. the latitude; 3. the courſe the ſhip has run; 4. the diſtance, that is, the way ſhe has made, or the number of leagues or miles ſhe has run in that courſe, from the place of the laſt obſervation. Now any two of theſe being known, the reſt may be eaſily found.

Having thus given ſome general idea of navigation, we now proceed to the problems by which the caſes of ſailing are ſolved on the globe.

PROBLEM XLIV.

Given the difference of latitude, and difference of longitude, to find the courſe and diſtance ſailed.*

Example. Admit a ſhip ſails from a port A, in latitude 38 deg. to another port B, in latitude 5 deg. and finds her difference of longitude 43 deg.

Let the port A be brought to the meridian, and elevate the globe to the given latitude of that port 38 deg. and fixing the quadrant of altitude preciſely over it on the meridian, move the quadrant to lie over the ſecond port B, (found by the given difference of latitude and longitude) then will it cut in the horizon 50 deg. 45 min. for the angle of the SHIP'S COURSE to be ſteered from the port A. Alſo, count the degrees in the quadrant between the two ports, which you will find 51 deg.; this number multiplied by 60, (the nautical miles in a degree) will give 3060 for the diſtance run.

PROBLEM XLV.

Given the difference of latitude and courſe, to find the difference of longitude and diſtance ſailed.

Example. Admit a ſhip ſails from a port A, in

* See Martin on the Globes.

in 25 deg. north latitude, to another port B, in 30 deg. ſouth latitude, upon a courſe of 43 deg.

Bring the port A to the meridian, and rectify the globe to the latitude thereof 25 deg. where fix the quadrant of altitude, and place it ſo as to make an angle with the meridian of 43 deg. in the horizon, and obſerve where the edge of the quadrant interſects the parallel of 30 deg. ſouth latitude, for that is the place of the port B. Then count the number of degrees on the edge of the quadrant interſected between the two ports, and there will be found 73 deg. which multiplied by 60, gives 4380 miles for the diſtance ſailed. As the two ports are now known, let each be brought to the meridian, and obſerve their difference of longitude in the equator reſpectively, which will be found 50 deg.

N. B. Had this problem been ſolved by LOXODROMICS, or ſailing on a rhumb, the difference of longitude would then have been 52 deg. 30 min. between the two ports.

PROBLEM XLVI.

Given the difference of latitude and diſtance run, to find the difference of longitude, and angle of the courſe.

Example. Admit a ſhip ſails from a port A, in latitude 50 deg. to another port B, in latitude 17 deg. 30 min. and her diſtance run be 2220 miles. Rectify the globe to the latitude of the

place

place A, then the diſtance run, reduced to degrees, will make 37 deg. which are to be reckoned from the end of the quadrant lying over the port A, under the meridian; then is the quadrant to be moved, till the 37 deg. coincides with the parallel of 17 deg. 30 min. north latitude; then will the angle of the courſe appear in the arch of the horizon, intercepted between the quadrant and the meridian, which will be 32 deg. 40 min.; and by making a mark on the globe for the port B, and bringing the ſame to the meridian, you will obſerve what number of degrees paſs under the meridian, which will be 20, the difference of longitude required.

PROBLEM XLVII.

Given the difference of longitude and courſe, to find the difference of latitude and diſtance ſailed.

Example. Suppoſe a ſhip ſails from A, in the latitude 51 deg. on a courſe making an angle with the meridian of 40 deg. till the difference of longitude be found juſt 20 deg.; then rectifying the globe to the latitude of the port A, place the quadrant of altitude ſo as to make an angle of 40 deg. with the meridian; then obſerve in what point it interſects the meridian paſſing through the given longitude of the port B, and there make a mark to repreſent the ſaid port; then the number of degrees intercepted between that and the port A will be 28, which will give

1680

1680 miles for the diſtance run. And the ſaid mark for the port B, being brought to the meridian, will have it's latitude there ſhewn to be 27 deg. 40 min.

PROBLEM XLVIII.

Given the courſe and diſtance ſailed, to find the difference of longitude, and difference of latitude.

Example. Suppoſe a ſhip ſails 1800 miles from a port A, 51 deg. 15 min. ſouth-weſt, on an angle of 45 deg. to another port B.

Having rectified the globe to the port A, fix the quadrant of altitude over it in the zenith, and place it to the ſouth-weſt point in the horizon; then upon the edge of the quadrant under 30 deg. (equal to 1800 miles from the port A) is the port B; which bring to the meridian, and you will there ſee the latitude; and at the ſame time, it's longitude in the equator, in the point cut by the meridian.

In all theſe caſes, the ſhip is ſuppoſed to be kept upon the ARCH OF A GREAT CIRCLE, which is not difficult to be done, very nearly, by means of the globe, by frequently obſerving the latitude, meaſuring the diſtance ſailed, and (when you can) finding the difference of longitude; for one of theſe being given, the place and courſe of the ſhip is known at the ſame time; and therefore the preceding courſe may be altered, and rectified without any trouble, through the whole

voyage, as often as ſuch obſervations can be obtained, or it is found neceſſary. Now if any of theſe DATA are but of the quantity of four or five degrees, it will ſuffice for correcting the ſhip's courſe by the globe, and carrying her directly to the intended port, according to the following problem.

PROBLEM XLIX.

To ſteer a ſhip upon the arch of a great circle by the given difference of latitude, or difference of longitude, or diſtance failed in a given time.

Admit a ſhip fails from a port A, to a very diſtant port Z, whoſe latitude and longitude are given, as well as it's geographical bearing from A; then,

Firſt, having rectified the globe to the port A, lay the quadrant of altitude over the port Z, and draw thereby the arch of a great circle through A and Z; this will deſign the intended path or tract of the ſhip.

Secondly, having kept the ſhip upon the firſt given courſe for ſome time, ſuppoſe by an obſervation you find the latitude of the PRESENT PLACE of the ſhip, this added to, or ſubducted from the latitude of the port A, will give the preſent latitude in the meridian; to which bring the path of the ſhip, and the part therein, which lies under the new latitude, is the true place B of the ſhip in the great arch. To the latitude of B rectify

rectify the globe, and lay the quadrant over Z, and it will ſhew in the horizon the NEW COURSE to be ſteered.

Thirdly, ſuppoſe the ſhip to be ſteered upon this courſe, till her diſtance run be found 300 miles, or 5 deg.; then, the globe being rectified to the place B in the zenith, laying the quadrant from thence over the great arch, make a mark at the 5th degree from B, and that will be the preſent place of the ſhip, which call C; which being brought to the meridian, it's latitude and longitude will be known. Then rectify the globe to the place C, and laying the quadrant from thence to Z, the new courſe to be ſteered will appear in the horizon.

Fourthly, having ſteered ſome time upon this new courſe, ſuppoſe, by ſome means or other, you come to know the difference of longitude of the preſent place of the ſhip, and of any of the preceding places, C, B, A; as B, for inſtance; then bring B to the meridian, and turn the globe about, till ſo many degrees of the equator paſs under the meridian, as are equal to the diſcovered difference of longitude; then the point of the great arch cut by the meridian, is the preſent place D of the ſhip, to which the new courſe is to be found as before.

And thus, by repeating theſe obſervations at proper intervals, you will find future places, E, F, G, &c. in the great arch; and by rectifying

the

the courſe at each, your ſhip will be conducted on the great circle, or the neareſt way from the port A to Z, by the USE OF THE GLOBE only.

OF THE GENERAL DISTRIBUTION OF LAND AND WATER IN THE TERRAQUEOUS GLOBE, WITH SOME OTHER GEOGRAPHICAL OBSERVATIONS.

Though the nature of our plan does not permit us to enter into many geographical diſquiſitions, yet we preſume the following general view will not be deemed irrelative to the ſubject; as, while it tends to bring the pupil acquainted with the grand outline of the globe, it will be a pleaſing relief from the more abſtruſe part in which he has been exerciſed.

If the pupil conſiders the terreſtrial globe as a map, he will find that land and water are generally contraſted to one another on the oppoſite ſide of the world; that is, if there be land on one ſide, it is anſwered by water in the antipodes. Thus for inſtance, the circumpolar parts of the northern hemiſphere conſiſt chiefly of land; but the circumpolar parts of the ſouth conſiſt almoſt entirely of water. It was formerly thought, that as there is ſo much land about the north pole, land would alſo have been found about the ſouth pole, to have ballanced it. But the diſcoveries of our circum-navigators

tors have ſhewn, that no ſuch land is to be met with; nor ought it to have been expected, for land on one ſide is ballanced by water on the oppoſite. *

If you bring the Cape of Good Hope under the ſtrong braſs meridian, this meridian will paſs through the heart of the continents of Europe and Africa; but the oppoſite ſemicircle paſſes through the middle of the great ſouth ſea. When the middle of the northern continent of America, about the meridian of Mexico, is examined in the ſame way, the oppoſite part paſſes through the middle of the Indian ocean. The ſouthern continent of New Holland is oppoſite to the Atlantic ocean. This alternation of land and water is too regular to have been caſual; but of the reaſon for it, or the benefits ariſing from it, we are altogether ignorant.

There is another phænomenon which is more level to our capacity, the manifeſt ſuperiority of the northern hemiſphere of the world over the ſouthern. It has more land, more ſun, more light, more heat, more arts, more ſenſe, more learning, more truth, more religion. The land of the ſouthern hemiſphere, that is, the land which lies on the other ſide of the equinoctial line, does not amount to one-fourth part of what is found on the north ſide.

The

* Jones's Phyſiological Diſquiſitions.

The ſun, from the eccentricity of the earth's orbit, and the ſituation of the aphelion, makes our ſummer eight days longer than the ſummer of the other hemiſphere, which in the ſpace of 4000 years amounts to more than 87 years.

The temperature of the earth and atmoſphere in the higher northern latitudes, is much more mild and moderate than in the correſpondent ſouthern latitudes. The dreary face of Staten land, with the weather-beaten Cape of South America, a climate ſo ſevere, as ſcarcely to admit of any human inhabitant, is not nearer to the pole than the northern counties of England, while the difference in the atmoſphere and the aſpect of the earth is almoſt incredible.

The nights of the northern hemiſphere diſplay a richer canopy than thoſe of the ſouthern. The ſtars of ſuperior magnitude are more numerous on this ſide the equinoctial than on the other. When the ſun is remote from us in winter, our longeſt nights are illuminated by the principal ſtars of the firmament. When the ſun enters Capricorn, the whole conſtellation of Orion, the brighteſt in the heavens, comes to the meridian about midnight, with ſeveral other ſtars of the firſt magnitude. If the midwinter of the ſouthern hemiſphere be compared, the inferiority of the nocturnal illumination is wonderful, and will be evident

to

to any one who examines the problem on a celeſtial globe.

The intellectual advantages of the northern hemiſphere are equally conſpicuous with the natural advantages. In the one, the arts and ſciences have always flouriſhed; but where are the poets, the hiſtorians, the orators, the philoſophers, of the ſouthern world? We may as well ſearch for the ſciences among the beaſts of the wilderneſs. There would be no end, if we were to continue the compariſon through all the ſeveral improvements which may be comprehended under the name of humanity; for here we have every thing that can adorn the human life, and there they can have nothing. He that conſiders the ſubject, will find that the natural and intellectual advantages always correſpond to each other.

Every habitable latitude enjoys a heat of 60 degrees at leaſt, for two months; which heat ſeems neceſſary for the growth and maturity of corn. The quickneſs of vegetation in the higher latitudes, proceeds from the duration of the ſun over the horizon. Rain is little wanted, as the earth is ſufficiently moiſtened by the melting of the ſnow that covers it during the winter: circumſtances, which, among many others, evince the wiſe diſpoſition of things by divine providence.

It is owing to the ſame provident hand that the globe of the earth is interſected with ſeas and mountains, in a manner that on it's firſt appearance ſeems altogether irregular and fortuitous, preſenting to the uninformed eye the view of an immenſe ruin; but when the effects of theſe ſeeming irregularities on the face of the globe, are carefully inſpected, they are found moſt beneficial, and even neceſſary to the welfare of it's inhabitants; for to ſay nothing of the advantages of trade and commerce, which could not exiſt without theſe ſeas, it is by them that the cold of the higher, and the heat of the lower latitude, is moderated. It is by the want of ſeas, that the interior parts of Aſia, as Siberia and Great Tartary, as well as thoſe of Africa, are rendered almoſt uninhabitable. In the ſame manner, mountains are neceſſary, not only as the ſources of rivers, but as a defence againſt heat, in the warm latitudes; without the Alps, Pyrenees, Apenine, the mountains Dauphine and Auvergne, Italy, Spain, and France, would be deprived of the mild air they now enjoy. Without the Balgate hills, or Indian Apenine, India would have been a deſert. Hence Jamaica, St. Domingo, Sumatra, and moſt other intertropical iſlands, are furniſhed with mountains, from which proceed the breezes by which they are refreſhed.*

ESSAY

* Kirwan on Climates.

ESSAY II.

PART IV.

Of the Use of the Celestial Globe.

THE celeſtial globe is an artificial repreſentation of the heavens, having the fixed ſtars drawn upon it, in their natural order and ſituation; whilſt it's rotation on it's axis repreſents the apparent diurnal motion of the ſun, moon, and ſtars.

It is not known how early the ancients had any thing of this kind: we are not certain what the ſphere of Atlas or Muſæus was; perhaps Palamedes, who lived about the time of the Trojan war, had ſomething of this kind; for of him it is ſaid,

To mark the ſigns that cloudleſs ſkies beſtow,
To tell the ſeaſons, when to ſail and plow,
He firſt deviſed; each planet's order found,
It's diſtance, period, in the blue profound.

From Pliny it would ſeem that Hipparchus had a celeſtial globe with the ſtars delineated upon it.

It is not to be ſuppoſed that the celeſtial globe

is ſo juſt a repreſentation of the heavens as the terreſtrial globe is of the earth; becauſe here the ſtars are drawn upon a convex ſurface, whereas they naturally appear in a concave one. But ſuppoſe the globe were made of glaſs, then to an eye placed in the center, the ſtars which are drawn upon it would appear in a concave ſurface, juſt as they do in the heavens.

Or if the reader was to ſuppoſe that holes were made in each ſtar, and an eye placed in the center of the globe, it would view, through thoſe holes, the ſame ſtars in the heavens that they repreſent.

As the terreſtrial globe, by turning on it's axis, repreſents the real diurnal motion of the earth; ſo the celeſtial globe, by turning on it's axis, repreſents the apparent diurnal motion of the heavens.

For the ſake of perſpicuity, and to avoid continual references, it will be neceſſary to repeat here ſome articles which have been already mentioned.

The ecliptic is that graduated circle which croſſes the equator in an angle of about $23\frac{1}{2}$ degrees, and the angle is called the obliquity of the ecliptic.

This circle is divided into twelve equal parts, conſiſting of 30 degrees each; the beginnings of them are marked with characters, repreſenting the twelve ſigns.

Aries

Aries ♈, Taurus ♉, Gemini ♊, Cancer ♋, Leo ♌, Virgo ♍, Libra ♎, Scorpio ♏, Sagittarius ♐, Capricornus ♑, Aquarius ♒, Piſces ♓.

Upon my father's globes, juſt under the ecliptic, the months, and days of each month, are graduated, for the readier fixing the artificial ſun upon it's place in the ecliptic.

The two points where the ecliptic croſſes the equinoctial, (the circle that anſwers to the equator on the terreſtrial globe) are called the equinoctial points; they are at the beginnings of Aries and Libra, and are ſo called, becauſe when the ſun is in either of them, the day and night is every where equal.

The firſt points of Cancer and Capricorn are called ſolſtitial points; becauſe when the ſun arrives at either of them, he ſeems to ſtand in a manner ſtill for ſeveral days, in reſpect to his diſtance from the equinoctial; when he is in one ſolſtitial point, he makes to us the longeſt day; when in the other, the longeſt night.

The latitude and longitude of ſtars are determined from the ecliptic.

The longitude of the ſtars and planets is reckoned upon the ecliptic; the numbers beginning at the firſt points of Aries ♈, where the ecliptic croſſes the equator, and increaſe according to the order of the ſigns.

Thus ſuppoſe the ſun to be in the 10th degree of Leo, we ſay, his longitude, or place, is four ſigns, ten degrees; becauſe he has already paſſed the four ſigns, Aries, Taurus, Gemini, Cancer, and is ten degrees in the fifth.

The latitude of the ſtars and planets is determined by their diſtance from the ecliptic upon a ſecondary or great circle paſſing through it's poles, and croſſing it at right angles.

Twenty-four of theſe circular lines, which croſs the ecliptic at right angles, being fifteen degrees from each other, are drawn upon the ſurface of our celeſtial globe; which being produced both ways, thoſe on one ſide meet in a point on the northern polar circle, and thoſe on the other meet in a point on the ſouthern polar circle.

The points determined by the meeting of theſe circles are called the poles of the ecliptic, one north, the other ſouth.

From theſe definitions it follows, that longitude and latitude on the celeſtial globe bear juſt the ſame relation to the ecliptic, as they do on the terreſtrial globe to the equator.

Thus as the longitude of places on the earth is meaſured by degrees upon the equator, counting from the firſt meridian; ſo the longitude of the heavenly bodies is meaſured by degrees upon the ecliptic, counting from the firſt point of Aries.

And

And as latitude on the earth is meaſured by degrees upon the meridian, counting from the equator; ſo the latitude of the heavenly bodies is meaſured by degrees upon a circle of longitude, counting either north or ſouth from the ecliptic.

The ſun, therefore, has no latitude, being always in the ecliptic; nor do we uſually ſpeak of his longitude, but rather of his place in the ecliptic, expreſſing it by ſuch a degree and minute of ſuch a ſign, as 5 degrees of Taurus, inſtead of 35 degrees of longitude.

The diſtance of any heavenly body from the equinoctial, meaſured upon the meridian, is called it's declination.

Therefore, the ſun's declination, north or ſouth, at any time, is the ſame as the latitude of any place to which he is then vertical, which is never more than $23\frac{1}{2}$ degrees.

Therefore all PARALLELS OF DECLINATION on the celeſtial globe are the very ſame as parallels of latitude on the terreſtrial.

Stars may have north latitude and ſouth declination, and vice verſa.

That which is called longitude on the terreſtrial globe, is called RIGHT ASCENSION on the celeſtial; namely, the ſun or ſtars diſtance from that meridian which paſſes through the firſt point of Aries, counted on the equinoctial.

Aſtronomers alſo ſpeak of OBLIQUE ASCENSION and DESCENSION, by which they mean the diſtance of that point of the equinoctial from the firſt point of Aries, which in an oblique ſphere riſes or ſets, at the ſame time that the ſun or ſtar riſes or ſets.

ASCENSIONAL difference is the difference betwixt right and oblique aſcenſion. The ſun's aſcenſional difference turned into time, is juſt ſo much as he riſes before or after ſix o'clock.

The celeſtial ſigns and conſtellations on the ſurface of the celeſtial globe, are repreſented by a variety of human and other figures, to which the ſtars that are either in or near them, are referred.

The ſeveral ſyſtems of ſtars which are applied to thoſe images, are called conſtellations. Twelve of theſe are repreſented on the ecliptic circle, and extend both northward and ſouthward from it. So many of thoſe ſtars as fall within the limits of 8 degrees on both ſides of the ecliptic circle, together with ſuch parts of their images as are contained within the aforeſaid bounds, conſtitute a kind of broad hoop, belt, or girdle, which is called the ZODIAC.

The names and the reſpective characters of the twelve ſigns of the ecliptic may be learned by inſpection on the ſurface of the broad paper circle, and the conſtellations from the globe itſelf.

The

The zodiac is reprefented by eight circles parallel to the ecliptic, on each fide thereof; thefe circles are one degree diftant from each other, fo that the whole breadth of the zodiac is 16 degrees.

Amongft thefe parallels, the latitude of the planets is reckoned; and in their apparent motion they never exceed the limits of the zodiac.

On each fide of the zodiac, as was obferved, other conftellations are diftinguifhed; thofe on the north fide are called northern, and thofe on the fouth fide of it, fouthern conftellations.

Of the Precession of the Equinoxes.

All the ftars which compofe thefe conftellations, are fuppofed to increafe their longitude continually; upon which fuppofition, the whole ftarry firmament has a flow motion from weft to eaft; infomuch that the firft ftar in the conftellation of Aries, which appeared in the vernal interfection of the equator and ecliptic in the time of Meton the Athenian, upwards of 1900 years ago, is now removed about 30 degrees from it.

This change of the ftars in longitude, which has now become fufficiently apparent, is owing to a fmall retrograde motion of the equinoctial points, of about 50 feconds in a year, which is occafioned by the attraction of the fun and moon

upon

upon the protuberant-matter about the equator. The ſame cauſe alſo occaſions a ſmall deviation in the paralleliſm of the earth's axis, by which it is continually directed towards different points in the heavens, and makes a complete revolution round the ecliptic in about 25,920 years. The former of theſe motions is called THE PRECESSION OF THE EQUINOXES, the latter THE NUTATION OF THE EARTH'S AXIS. In conſequence of this ſhifting of the equinoctial points, an alteration has taken place in the ſigns of the ecliptic; thoſe ſtars which in the infancy of aſtronomy were in Aries, being now got into Taurus, thoſe of Taurus into Gemini, &c. ſo that the ſtars which roſe and ſet at any particular ſeaſon of the year, in the times of Heſiod, Eudoxus, and Virgil, will not at preſent anſwer the deſcriptions given of them by thoſe writers.

TO REPRESENT THE MOTION OF THE EQUINOCTIAL POINTS BACKWARDS, OR IN ANTECEDENTIA, UPON THE CELESTIAL GLOBE, elevate the north pole ſo that it's axis may be perpendicular to the plane of the broad paper circle, and the equator will then be in the ſame plane; let theſe repreſent the ecliptic, and then the poles of the globe will alſo repreſent thoſe of the ecliptic; the ecliptic line upon the globe will at the ſame time repreſent the equator, inclined in an angle of 23½ degrees to the broad paper circle, now called the ecliptic, and cutting it in two points,

points, which are called the equinoctial interfections.

Now if you turn the globe flowly round upon it's axis from eaft to weft, while it is in this pofition, thefe points of interfection will move round the fame way; and the inclination of the circle, which in fhewing this motion reprefents the equinoctial, will not be altered by fuch a revolution of the interfecting or equinoctial points. This motion is called the preceffion of the equinoxes, becaufe it carries the equinoctial points backwards amongft the fixed ftars.

The poles of the world feem to defcribe a circle from eaft to weft, round the poles of the ecliptic, arifing from the preceffion of the equinox. It is a very flow motion, for the equinoctial points take up 72 years to move one degree, and therefore they are 25,920 years in defcribing 360 degrees, or completing a revolution.

This motion of the poles is eafily reprefented by the above-defcribed pofition of the globe, in which, if the reader remembers, the broad paper circle reprefents the ecliptic, and the axis of the globe being prependicular thereto, reprefents the axis of the ecliptic; and the two points, where the circular lines meet, will reprefent the poles of the world, whence as the globe is flowly turned from eaft to weft, thefe points will revolve the fame way about the poles of the globe, which

are

are here ſuppoſed to repreſent the poles of the ecliptic. The axis of the world may revolve as above, although it's ſituation, with reſpect to the ecliptic, be not altered; for the points here ſuppoſed to repreſent the poles of the world, will always keep the ſame diſtance from the broad paper circle, which repreſents the ecliptic in this ſituation of the globe.*

From the different degrees of brightneſs in the ſtars, ſome appear to be greater than others, or nearer to us; on our celeſtial globe they are diſtinguiſhed into ſeven different magnitudes.

* Rutherforth's Syſtem of Nat. Philoſ. vol. ii. p. 730.

OF THE

USE OF THE CELESTIAL GLOBE,

IN THE SOLUTION OF

PROBLEMS RELATIVE TO THE SUN.

EVERY thing that relates to the ſun is of ſuch importance to man, that in all things he claims a natural preheminence. The ſun is at once the moſt beautiful emblem of the Supreme

preme Being, and, under his influence, the foſtering parent of worlds; being preſent to them by his rays, cheering them by his countenance, cheriſhing them by his heat, adorning them at each returning ſpring with the gayeſt and richeſt attire, illuminating them with his light, and feeding the lamp of life.

To the ancients he was known under a variety of names, each characteriſtic of his different effects; he was their Hercules, the great deliverer, the reſtorer of light out of darkneſs, the diſpenſer of good, continually labouring for the happineſs of a depraved race. He was the Mithra of the Perſians, a word derived from love, or mercy, becauſe the whole world is cheriſhed by him, and feels as it were the effects of his love.

In the ſacred ſcriptures, the original ſource of all emblematical writings, our Lord is called our ſun, and the ſun of righteouſneſs; and as there is but one ſun in the heavens, ſo there is but one true God, the maker and redeemer of all things, the light of the underſtanding, and the life of the ſoul.

As in ſcripture our God is ſpoke of as a ſhield and buckler, ſo the ſun is characterized by this mark ⊙ repreſenting a ſhield or buckler, the middle point the umbo, or boſs; becauſe it is love, or life, which alone can protect from fear and death.

His

His celeſtial rays, like thoſe of the ſun, take their circuit round the earth; there is no corner of it ſo remote as to be without the reach of their vivifying and penetrating power. As the material light is always ready to run it's heavenly race, and daily iſſues forth with renewed vigour, like an invincible champion, ſtill freſh to labour; ſo likewiſe did our REDEEMING GOD rejoice to run his glorious race, he excelled in ſtrength, and triumphed, and continues to triumph over all the powers of darkneſs, and is ever manifeſting himſelf as the deliverer, the protector, the friend, and father of the human race. *

PROBLEM L.

To rectify the celeſtial globe.

To rectify the celeſtial globe, is to put it in that poſition in which it may repreſent exactly the apparent motion of the heavens.

In different places, the poſition will vary, and that according to the different latitude of the places. Therefore, to rectify for any place, find firſt, by the terreſtrial globe, the latitude of that place.

The latitude of the place being found in degrees, elevate the pole of the celeſtial globe the ſame number of degrees and minutes above the plane of the horizon, for this is the name given to

* Horne on the Pſalms.

to the broad paper circle, in the ufe of the celeftial globe.

Thus the latitude of London being $51\frac{1}{2}$ degrees, let the globe be moved till the plane of the horizon cuts the meridian in that point.

The next rectification is for the fun's place, which may be performed as directed in pr. xxix; or look for the day of the month clofe under the ecliptic line, againft which is the fun's place, place the artificial fun over that point, then bring the fun's place to the graduated edge of the ftrong brazen meridian, and fet the hour index to the moft elevated twelve.

Thus on the 24th of May the fun is in $3\frac{1}{2}$ degrees of Gemini, and is fituated near the bull's eye and the feven ftars which are not then vifible, on account of his fuperior light. If the fun were on that day to fuffer a total eclipfe, thefe ftars would then be feen fhining with their accuftomed brightnefs.

Laftly, fet the meridian of the globe north and fouth, by the compafs.

And the globe will be rectified, or put into a fimilar pofition, to the concave furface of the heavens, for the given latitude.

PROBLEM LI.

To find the declination of the fun for any given day in the year.

Seek the day of the month clofe under the

ecliptic line, againſt which is the ſun's place; bring that point under the ſtrong braſs meridian, and the degree that ſtands over it is the ſun's declination for that day.

Thus, on the 23d of May the ſun's declination will be about 23 deg. 10 min.; and upon the 23d of Auguſt it will be 11 deg. 13 min.

PROBLEM LII.

To find the ſun's right aſcenſion.

The right aſcenſion of the ſun, &c. is an arch of the equinoctial contained between the beginning of Aries, and that point of it which comes to the meridian with it.

Therefore, bring the ſun's place to the meridian, and that point of the equinoctial which is under the meridian will ſhew the ſun's right aſcenſion.

Thus on the 11th of May the right aſcenſion will be found to be 47 deg. 10 min.

By the two laſt problems, we ſee that the right aſcenſion and declination is found after the ſame manner as the longitude and latitude of a place upon the terreſtrial globe.

Bring the ſun's place to the weſtern edge of the horizon, and the degree of the equator, cut by the horizon, is his oblique deſcenſion; carry him round to the eaſtern ſide, and you will there find his oblique aſcenſion.

PROBLEM LIII.

The latitude of the place and the ſun's place being given, to find the ſun's amplitude.

That degree from the eaſt or weſt in the horizon, wherein any object riſes or ſets, is called the AMPLITUDE.

Rectify the globe to the latitude of the place, and bring the ſun's place to the eaſtern ſide of the meridian, and the arch of the horizon intercepted between that point and the eaſtern point, will be the ſun's amplitude at riſing,

If the ſame point be brought to the weſtern ſide of the horizon, the arch of the horizon intercepted between that point and the weſtern point, will be the ſun's amplitude at ſetting.

Thus on the 24th of May the ſun riſes at four, with 36 degrees of eaſtern amplitude, that is, 36 degrees from the eaſt towards the north, and ſets at eight, with 36 degrees of weſtern amplitude.

The amplitude of the ſun at riſing and ſetting increaſes with the latitude of the place: and in very high northern latitudes, the ſun ſcarce ſets before he riſes again. Homer had heard ſomething of this, though it is not true of the Læſtrygones, to whom he applies it.

Six days and nights a doubtful courſe we ſteer;
The next, proud LAMOS' lofty towers appear,
And Læſtrygonia's gates ariſe diſtinct in air.

The ſhepherd quitting here at night the plain,
Calls, to ſucceed his cares, the watchful ſwain.
But he that ſcorns the chains of ſleep to wear,
And adds the herdſman's to the ſhepherd's care,
So near the paſtures, and ſo ſhort the way,
His double toils may claim a double pay,
And join the labours of the night and day.

PROBLEM LIV.

To find the ſun's altitude at any given time of the day.

Set the center of the artificial ſun to his place in the ecliptic upon the globe, and rectify it to the latitude and zenith; bring the center of the artificial ſun under the ſtrong braſs meridian, and ſet the hour index to that XII which is moſt elevated; turn the globe to the given hour, and move the graduated edge of the quadrant to the center of the artificial ſun; and that degree on the quadrant which is cut by the ſun's center, is the ſun's height at that time.

The artificial ſun being brought under the ſtrong braſs meridian, and the quadrant laid upon it's center, will ſhew it's meridian, or greateſt altitude, for that day.

If the ſun be in the equator, his greateſt or meridian altitude is equal to the elevation of the equator, which is always equal to the co-latitude of the place.

Thus on May 24, at nine o'clock, the ſun has about

about 44 degrees of altitude, and at ſix in the evening of the ſame day, his altitude will be about 20 degrees.

OF THE AZIMUTHAL, OR VERTICAL CIRCLES.

The vertical point, that is, the uppermoſt point of the celeſtial globe, repreſents a point in the heavens, directly over our heads, which is called our zenith.

From this point circular lines may be conceived croſſing the horizon at right angles.

Theſe are called AZIMUTH or VERTICAL CIRCLES. That one which croſſes the horizon at 10 deg. diſtance from the meridian on either ſide, is called an azimuth circle of 10 deg.; that which croſſes at 20, is called an azimuth of 20 deg.

The azimuth of 90 deg. is called the PRIME VERTICAL: it croſſes the horizon at the eaſtern and weſtern points.

Any AZIMUTH CIRCLE may be repreſented by the graduated edge of the braſs quadrant of altitude, when the center upon which it turns is ſcrewed to that point of the ſtrong braſs meridian which anſwers to the latitude of the place, and the place is brought into the zenith. See prob. XXX.

If the ſaid graduated edge ſhould lie over the ſun's center or place, at any given time, it will repreſent the ſun's azimuth at that time.

If the graduated edge be fixed at any point, fo as to reprefent any particular azimuth, and the fun's place be brought there, the horary index will fhew at what time of that day the fun will be in that particular azimuth.

Here it may be obferved, that the AMPLITUDE and azimuth are much the fame.

The amplitude fhewing the bearing of any object WHEN IT RISES OR SETS, from the EAST and WEST points of the horizon.

The azimuth the bearing of any object when it is ABOVE THE HORIZON, either from the NORTH or SOUTH points thereof. Thefe defcriptions and illuftrations being underftood, we may proceed to

PROBLEM LV.

The latitude, the fun's place, and his altitude, being given; to find the hour of the day, and the fun's azimuth from the meridian.

Having rectified the globe for the latitude, the zenith, and the fun's place, turn the globe and the quadrant of altitude, fo that the fun's place may cut the given degree of altitude: then the index will fhew the hour, and the quadrant will cut the azimuth in the horizon. Thus, if at London, on the 21ft of Auguft, the fun's altitude be 36 deg. in the forenoon, the hour of the day will be IX, and the fun's azimuth about 58 deg. from the fouth part of the meridian.

PROBLEM

PROBLEM LVI.

The latitude, hour of the day, and the ſun's place being given, to find the ſun's altitude and azimuth.

Rectify the globe for the latitude, the zenith, and the ſun's place, then the number of degrees contained betwixt the ſun's place and the vertex, is the ſun's meridional zenith diſtance; the complement of which to 90 deg. is the ſun's meridian altitude. If you turn the globe about until the index points to any other given hour, then bringing the quadrant of altitude to cut the ſun's place, you will have the ſun's altitude at that hour; and where the quadrant cuts the horizon, is the ſun's azimuth at the ſame time. Thus May the 1ſt at London, the ſun's meridian altitude will be 53½ deg.; and at 10 o'clock in the morning, the ſun's altitude will be 46 deg. and his azimuth about 46 deg. from the ſouth part of the meridian.

PROBLEM LVII.

The latitude of the place, and the day of the month being given; to find the depreſſion of the ſun below the horizon, and the azimuth at any hour of the night.

Having rectified the globe for the latitude, the zenith, and the ſun's place, take a point in the ecliptic exactly oppoſite to the ſun's place,

and find the ſun's altitude and azimuth, as by the laſt problem, and theſe will be the depreſſion and the altitude required.

Thus if the time given be the 1ſt of November, at 10 o'clock at night, the depreſſion and azimuth will be the ſame as was found in the laſt problem.

PROBLEM LVIII.

The latitude, the ſun's place, and his azimuth being given, to find his altitude, and the hour.

Rectify the globe for the latitude, the zenith, and the ſun's place; then put the quadrant of altitude to the ſun's azimuth in the horizon, and turn the globe till the ſun's place meets the edge of the quadrant, then the ſaid edge will ſhew the altitude, and the index point to the hour.

Thus, May 21ſt, at London, when the ſun is due eaſt, his altitude will be about 24 degrees, and the hour about VII in the morning; and when his azimuth is 60 degrees ſouth-weſterly, the altitude will be about 44 $\frac{1}{2}$ degrees, and the hour about 2 $\frac{3}{4}$ in the afternoon.

Thus the latitude and the day being known, and having beſides either the altitude, the azimuth, or the hour, the other two may be eaſily found.

PROBLEM

PROBLEM LIX.

The latitude, the ſun's altitude, and his azimuth being given, to find his place in the ecliptic, and the hour.

Rectify the globe for the latitude and zenith, and ſet the edge of the quadrant to the given azimuth; then turning the globe about, that point of the ecliptic which cuts the altitude, will be the ſun's place. Keep the quadrant of altitude in the ſame poſition, and having brought the ſun's place to the meridian, and the hour index to 12 at noon, turn the globe about till the ſun's place cuts the quadrant of altitude, and then the index will point the hour of the day.

PROBLEM LX.

The declination and meridian altitude of the ſun, or of any ſtar being given, to find the latitude of the place.

Mark the point of declination upon the meridian, according as it is either north or ſouth from the equator; then ſlide the meridian up or down in the notches, till the point of declination be ſo far diſtant from the horizon, as is the given meridian altitude; that elevation of the pole will be the latitude.

Thus if the ſun's, or any ſtar's meridian altitude be 50 degrees, and it's declination be 11 $\frac{1}{2}$

 degrees

degrees north, the latitude will be 51 ½ degrees north.

PROBLEM LXI.

To find the length of any day in the year, in any latitude, not exceeding 66 ½ degrees.

Elevate the celeſtial globe to the latitude, and ſet the center of the artificial ſun to his place upon the ecliptic line on the globe for the given day, and bring it's center to the ſtrong braſs meridian, placing the horary index to that XII which is moſt elevated; then turn the globe till the artificial ſun cuts the eaſtern edge of the horizon, and the horary index will ſhew the time of ſun-riſing; turn it to the weſtern ſide, and you obtain the hour of ſun-ſetting.

The length of the day and night will be obtained, by doubling the time of ſun-riſing and ſetting, as before.

PROBLEM LXII.

To find the length of the longeſt and ſhorteſt days in any latitude that does not exceed 66 ½ degrees.

Elevate the globe according to the latitude, and place the center of the artificial ſun for the longeſt day upon the firſt point of Cancer, but for the ſhorteſt day on the firſt point of Capricorn, then proceed as in the laſt problem.

But if the place hath ſouth latitude, the ſun is

in the firſt point of Capricorn on their longeſt day, and in the firſt point of Cancer on their ſhorteſt day.

PROBLEM LXIII.

To find the latitude of a place, in which it's longeſt day may be of any given length between twelve and twenty-four hours.

Set the artificial ſun to the firſt point of Cancer, bring it's center to the ſtrong braſs meridian, and ſet the horary index to XII; turn the globe till it points to half the number of the given hours and minutes; then elevate or depreſs the pole, till the artificial ſun coincides with the horizon, and that elevation of the pole is the latitude required.

PROBLEM LXIV.

To find the time of the ſun's riſing and ſetting, the length of day and night, on any place whoſe latitude lies between the polar circles; and alſo the length of the ſhorteſt day in any of thoſe latitudes, and in what climate they are.

Rectify the globe to the latitude of the given place, and bring the artificial ſun to his place in the ecliptic for the given day of the month; and then bring it's center under the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated.

Then bring the center of the artificial ſun to the

the eaſtern part of the broad paper circle, which in this caſe repreſents the horizon, and the horary index ſhews the time of the ſun-riſing; turn the artificial ſun to the weſtern ſide, and the horary index will ſhew the time of the ſun-ſetting.

Double the time of ſun-riſing is the length of the night, and the double of that of ſun-ſetting is the length of the day.

Thus on the 5th day of June, the ſun riſes at 3 h. 40 min. and ſets at 8 h. 20 min.; by doubling each number it will appear, that the length of this day is 16 h. 40 min. and that of the night 7 h. 20 min.

The longeſt day at all places in north latitude, is when the ſun is in the firſt point of Cancer. And,

The longeſt day to thoſe in ſouth latitude, is when the ſun is in the firſt point of Capricorn.

Wherefore, the globe being rectified as above, and the artificial ſun placed to the firſt point of Cancer, and brought to the eaſtern edge of the broad paper circle, and the horary index being ſet to that XII which is moſt elevated, on turning the globe from eaſt to weſt, until the artificial ſun coincides with the weſtern edge, the number of hours counted, which are paſſed over by the horary index, is the length of the longeſt day; their complement to twenty-four hours gives the length of the ſhorteſt night.

If twelve hours be ſubtracted from the length

of

of the longeſt day, and the remaining hours doubled, you obtain the climate mentioned by ancient hiſtorians: and if you take half the climate, and add thereto twelve hours, you obtain the length of the longeſt day in that climate. This holds good for every climate between the polar circles.

A climate is a ſpace upon the ſurface of the earth, contained between two parallels of latitude, ſo far diſtant from each other, that the longeſt day in one, differs half an hour from the longeſt day in the other parallel.

PROBLEM LXV.

The latitude of a place being given in one of the polar circles, (ſuppoſe the northern) to find what number of days (of 24 hours each) the ſun doth conſtantly ſhine upon the ſame, how long he is abſent, and alſo the firſt and laſt day of his appearance.

Having rectified the globe according to the latitude, turn it about until ſome point in the firſt quadrant of the ecliptic (becauſe the latitude is north) interſects the meridian in the north point of the horizon; and right againſt that point of the ecliptic, on the horizon, ſtands the day of the month when the longeſt day begins.

And if the globe be turned about till ſome point in the ſecond quadrant of the ecliptic cuts the meridian in the ſame point of the horizon, it will ſhew the ſun's place when the longeſt day ends,

ends, whence the day of the month may be found, as before; then the number of natural days contained between the times the longeſt day begins and ends, is the length of the longeſt day required.

Again, turn the globe about, until ſome point in the third quadrant of the ecliptic cuts the meridian in the ſouth part of the horizon; that point of the ecliptic will give the time when the longeſt night begins.

Laſtly, turn the globe about, until ſome point in the fourth quadrant of the ecliptic cuts the meridian in the ſouth point of the horizon; and that point of the ecliptic will be the place of the ſun when the longeſt night ends.

Or, the time when the longeſt day or night begins, being known, their end may be found by counting the number of days from that time to the ſucceeding ſolſtice; then counting the ſame number of days from the ſolſtitial day, will give the time when it ends.

Of the Equation of Time.

It is not poſſible in a treatiſe of this kind to enter into a diſquiſition of the nature of time. It is ſufficient to obſerve, that if we would with exactneſs eſtimate the quantity of any portion of infinite duration, or convey an idea of the ſame to others, we make uſe of ſuch known meaſures as have been originally borrowed from the motions

tions of the heavenly bodies. It is true, none of thefe motions are exactly equal and uniform, but are fubject to fome fmall irregularities, which, though of no confequence in the affairs of civil life, muft be taken into the account, in aftronomical calculation. There are other irregularities of more importance, one of which is in the inequality of the natural day.

It is a confideration that cannot be reflected upon without furprize, that wherever we look for commenfurabilities and equalities in nature, we are always difappointed. The earth is fpherical, but not perfectly fo; the fummer is unequal, when compared with the winter; the ecliptic difagrees with the equator, and never cuts it twice in the fame equinoctial point. The orbit of the earth has an eccentricity more than double in proportion to the fpheroidity of it's globe; no number of the revolutions of the moon coincide with any number of the revolutions of the earth in it's orbit: no two of the planets meafure one another: and thus it is wherever we turn our thoughts, fo different are the views of the Creator from our narrow conception of things; where we look for commenfuration, we find variety and infinity.

Thus ancient aftronomers looked upon the motion of the fun to be fufficiently regular for the menfuration of time; but by the accurate obfervations of later aftronomers, it is found that

neither

neither the days, nor even the hours, as meaſured by the ſun's apparent motion, are of an equal length on two accounts.

1ſt, A natural or ſolar day of 24 hours, is that ſpace of time the ſun takes up in paſſing from any particular meridian to the ſame again; but one revolution of the earth, with reſpect to a fixed ſtar, is performed in 23 hours, 56 minutes, 4 ſeconds; therefore, the unequal progreſſion of the earth through her elliptical orbit, (as ſhe takes almoſt eight days more to run through the northern half of the ecliptic, than ſhe does to paſs through the ſouthern) is the reaſon that the length of the day is not exactly equal to the time in which the earth performs it's rotation about it's axis.

2dly, From the obliquity of the ecliptic to the equator, on which laſt we meaſure time; and as equal portions of one do not correſpond to equal portions of the other, the apparent motion of the ſun would not be uniform; or, in other words, thoſe points of the equator which come to the meridian, with the place of the ſun on different days, would not be at equal diſtances from each other.

PROBLEM LXVI.

To illuſtrate, by the globe, the cauſes of the equation of time.

This laſt is eaſily ſeen upon the globe, by bringing

bringing every tenth degree of the ecliptic to the graduated ſide of the ſtrong braſs meridian, and you will find that each tenth degree on the equator will not come thither with it, but in the following order from ♈ to ♋, every tenth degree of the ecliptic comes ſooner to the ſtrong braſs meridian than their correſponding 10ths on the equator; thoſe in the ſecond quadrant of the ecliptic, from ♋ to ♎, come later, from ♎ to ♑ ſooner, and from ♑ to Aries later, whilſt thoſe at the beginning of each quadrant come to the meridian at the ſame time; therefore the ſun and clock would be equal at theſe four times, if the ſun was not longer in paſſing through one half of the ecliptic than the other, and the two inequalities joined together, compoſe that difference which is called the equation of time.

Theſe cauſes are independent of each other, ſometimes they agree, and at other times are contrary to one another.

The inequality of the natural day is the cauſe that clocks or watches are ſometimes before, ſometimes behind the ſun.

A good and well-regulated clock goes uniformly on throughout the year, ſo as to mark the equal hours of a natural day, of a mean length: a ſun-dial marks the hours of every day in ſuch a manner, that every hour is a 24th part of the time between the noon of that day, and the noon of the day immediately following. The

time

time meaſured by a clock is called equal or true time, that meaſured by the ſun-dial apparent time.

Of the Use of the Celestial Globe, in Problems relative to the Planets.

The ſituation of the fixed ſtars being always the ſame with reſpect to one another, they have their proper places aſſigned to them on the globe.

But to the planets no certain place can be aſſigned, their ſituation always varying.

That ſpace in the heavens, within the compaſs of which the planets appear, is called the zodiac.

The latitude of the planets ſcarce ever exceeding 8 degrees, the zodiac is ſaid to reach about 8 degrees on each ſide of the ecliptic.

Upon the celeſtial globe, on each ſide of the ecliptic, are drawn eight parallel circles, at the diſtance of one degree from each other, including a ſpace of 16 degrees; theſe are croſſed at right angles, with ſegments of great circles at every 5th degree of the ecliptic; by theſe, the place of a planet on the globe, on any given day, may be aſcertained with accuracy.

PROBLEM LXVII.

To find the place of any planet upon the globe, and by that means to find it's place in the heavens;

heavens; alfo, to find at what hour any planet will rife or fet, or be on the meridian, on any day in the year.

Rectify the globe to the latitude and fun's place, then find the planet's longitude and latitude in an ephemeris, and fet the graduated edge of the moveable meridian to the given longitude in the ecliptic, and counting fo many degrees amongft the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or fouth; and fet the center artificial fun to that point, and the center will reprefent the place of the planet for that time.

Or fix the quadrant of altitude over the pole of the ecliptic, and holding the globe faft, bring the edge of the quadrant to cut the given degree of longitude on the ecliptic; then feek the given latitude on the quadrant, and the place under it is the point fought.

While the globe moves about it's axis, this point moving along with it will reprefent the planet's motion in the heavens. If the planet be brought to the eaftern fide of the horizon, the horary index will fhew the time of it's rifing. If the artificial fun is above the horizon, the planet will not be vifible: when the planet is under the ftrong brazen meridian, the hour index fhews the time it will be on that circle in the heavens: when it is at the weftern edge, the time of it's fetting will be obtained.

PROBLEM LXVIII.

To find directly the planets which are above the horizon at sun-set, upon any given day and latitude.

Find the sun's place for the given day, bring it to the meridian, set the hour index to XII, and elevate the pole for the given latitude: then bring the place of the sun to the western semicircle of the horizon, and observe what signs are in that part of the ecliptic above the horizon, then cast your eye upon the ephemeris for that month, and you will at once see what planets possess any of those elevated signs; for such will be visible, and fit for observation on the night of that day.

PROBLEM LXIX.

To find the right ascension, declination, amplitude, azimuth, altitude; hour of the night, &c. of any given planet, for a day of a month and latitude given.

Rectify the globe for the given latitude and day of the month; then find the planet's place, as before directed, and then the right ascension, declination, amplitude, azimuth, altitude, hour, &c. are all found, as directed in the problems for the sun; there being no difference in the process, no repetition can be necessary.

Of

OF THE USE OF THE CELESTIAL GLOBE, IN PROBLEMS RELATIVE TO THE MOON.

From the ſun and planets we now proceed to thoſe problems that concern the moon, the brilliant ſatellite of our earth, which every month enriches it with it's preſence; by the mildneſs of it's light ſoftening the darkneſs of night; by it's influence affecting the tide; and by the variety of it's aſpects, offering to our view ſome very remarkable phænomena.

"Soon as the ev'ning ſhades prevail,
The moon takes up the wond'rous tale;
And nightly to the liſt'ning earth,
Repeats the ſtory of her birth:
Whilſt all the ſtars that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And ſpread the truth from pole to pole."

As the orbit of the moon is conſtantly varying in it's poſition, and the place of the node always changing, as her motion is even variable in every part of her orbit, the ſolutions of the problems which relate to her, are not altogether ſo ſimple as thoſe which concern the ſun.

The moon increaſes her longitude in the ecliptic every day, about 13 degrees, 10 minutes, by which means ſhe croſſes the meridian of any

place about 50 minutes later than ſhe did the preceding day.

Thus if on any day at noon her place (longitude) be in the 12th degree of Taurus, it will be 13 deg. 10 min. more, or 25 deg. 10 min. in Taurus on the ſucceeding noon.

It is new moon when the ſun and moon have the ſame longitude, or are in or near the ſame point of the eliptic.

When they have oppoſite longitudes, or are in oppoſite points of the ecliptic, it is full moon.

To aſcertain the moon's place with accuracy, we muſt recur to an ephemeris; but as even in moſt ephemerides the moon's place is only ſhewn at the beginning of each day, or XII o'clock at noon, it becomes neceſſary to ſupply by a table this deficiency, and aſſign thereby her place for any intermediate time.

In the nautical ephemeris, publiſhed under the authority of the Board of Longitude, we have the moon's place for noon and midnight, with rules for accurately obtaining any intermediate time; but as this ephemeris may not always be at hand, we ſhall inſert, from Mr. Martin's treatiſe on the globes, a table for finding the hourly motion of the moon. In order, however, to uſe this table, it will be neceſſary firſt TO FIND THE QUANTITY OF THE MOON'S DIURNAL MOTION IN THE ECLIPTIC, for any given day; for the quantity of the moon's diurnal motion varies

varies from about 11 deg. 46 min. the leaſt, to 15 deg. 16 min. when greateſt.

The following tables are calculated from the leaſt of 11 deg. 46 min. to the greateſt of 15 deg. 16 min. every column being increaſing 10 minutes; upon the top of the column is the quantity of the diurnal motion, and on the ſide of the table are the 24 hours, by which means it will be eaſy to find what part of the diurnal motion of the moon anſwers to any given number of hours.

Thus ſuppoſe the diurnal motion to be 12 32, look on the top column for the number neareſt to it, which you will find to be 12 36, in the ſixth column; and under it, againſt 9 hours, you will find 4 deg. 43 min. which is her motion in the ecliptic in the ſpace of 9 hours for that day. The quantity of the diurnal motion for any day is found by taking the difference between it and the preceding day.

Thus let the diurnal motion for the 11th of May, 1787, be required.

	SIGNS.	DEG.	MIN.
On the 11th of May her place was	11	2	35
On the 10th of May -	10	19	47
The diurnal motion ſought		12	48

TABLES

For finding the Hourly Motion of the Moon, and thereby her true Place at any Time of the Day.

TABLE I.

Hours.	11 46	11 56	12 6	12 16	12 26	12 36	12 46	12 56	13 6	13 16	13 26
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	0 29	0 30	0 30	0 30	0 31	0 31	0 32	0 32	0 33	0 33	0 34
2	0 59	1 0	1 0	1 1	1 2	1 33	1 4	1 5	1 5	1 6	1 43
3	1 28	1 20	1 31	1 32	1 33	1 35	1 36	1 37	1 38	1 39	1 41
4	1 58	1 59	2 1	2 3	2 4	2 6	2 8	2 9	2 11	2 13	2 14
5	2 27	2 29	2 31	2 34	2 35	2 37	2 40	2 42	2 44	2 46	2 48
6	2 57	2 59	3 1	3 4	3 6	3 9	3 11	3 14	3 16	3 19	3 21
7	3 26	3 29	3 32	3 35	3 38	3 40	3 43	8 46	3 49	3 52	3 55
8	3 55	3 59	4 2	4 6	4 9	4 12	4 15	4 19	4 22	4 25	4 29
9	4 25	4 28	4 32	4 36	4 40	4 43	4 47	4 51	4 55	4 58	5 2
10	4 54	4 58	5 3	5 7	5 11	5 1	5 19	5 23	5 27	5 32	5 56
11	5 24	5 28	5 33	5 37	5 42	5 4	5 51	5 56	6 0	6 3	6 9
12	5 53	5 58	6 3	6 8	6 13	6 18	6 23	6 28	6 33	6 38	6 43
13	6 22	6 28	6 33	6 39	6 44	6 49	6 55	7 0	7 6	7 11	7 17
14	6 52	6 58	7 3	7 9	7 15	7 21	7 27	7 33	7 38	7 44	7 50
15	7 21	7 27	7 34	7 40	7 46	7 52	7 59	8 5	8 11	8 17	8 24
16	7 51	7 57	8 4	8 11	8 17	8 24	8 31	8 37	8 44	8 51	8 57
17	8 20	8 27	8 34	8 41	8 48	8 55	9 3	9 10	9 17	9 24	9 31
18	8 49	8 57	9 4	9 12	9 19	9 27	9 34	9 42	9 49	9 57	10 4
19	9 19	9 26	9 35	9 43	9 51	9 58	10 6	10 14	10 22	10 30	10 38
20	9 48	9 56	10 5	10 13	10 21	10 30	10 38	10 47	10 55	11 3	11 12
21	10 17	10 26	10 36	10 44	10 53	11 1	11 10	11 19	11 27	11 36	11 43
22	10 47	10 56	11 6	11 15	11 21	11 33	11 42	11 51	12 0	12 10	12 19
23	11 17	11 26	11 36	11 46	11 55	12 4	12 14	12 24	12 33	12 43	12 52
24	11 46	11 56	12 6	12 16	12 26	12 36	12 46	12 56	13 6	13 16	13 26

TABLE

TABLE II.

HOURS.	13 30	13 40	13 50	14 6	14 16	14 26	14 36	14 46	14 56	15 6	15 16
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	0 31	0 34	0 35	0 36	0 36	0 36	0 36	0 37	0 37	0 38	0 38
2	1 8	1 9	1 16	1 10	1 11	1 12	1 13	1 14	1 15	1 15	1 16
3	1 42	1 42	1 46	1 46	1 47	1 48	1 49	1 51	1 51	1 53	1 54
4	2 16	2 8	2 19	2 21	2 22	2 24	2 26	2 28	2 20	2 31	2 33
5	2 50	2 52	2 54	2 56	2 58	8 0	3 3	3 5	3 7	3 9	3 11
6	3 24	3 26	3 29	3 31	3 34	3 39	3 39	3 41	3 45	3 46	3 9
7	3 58	4 1	4 4	4 7	4 10	4 19	4 15	4 18	4 21	4 24	4 7
8	4 32	4 35	4 39	4 42	4 45	4 49	4 52	4 55	4 59	5 2	5 5
9	5 6	5 10	5 13	5 17	4 21	5 25	5 28	5 32	5 36	5 40	5 43
10	5 40	5 42	5 48	5 52	5 67	6 1	6 5	6 9	6 13	6 17	6 22
11	6 14	6 19	6 23	6 28	6 32	6 37	6 41	6 46	6 51	6 55	7 0
12	6 48	6 53	6 50	7 3	7 8	7 13	7 28	7 23	7 28	7 33	7 28
13	7 22	7 27	7 33	7 38	7 44	7 49	7 54	8 6	8 5	8 11	8 10
14	7 56	8 0	8 8	8 13	8 19	8 25	8 31	8 37	8 43	8 48	8 54
15	8 30	8 36	8 42	8 49	8 55	9 1	9 7	9 14	9 20	9 26	9 32
16	9 4	9 11	9 17	9 21	9 12	9 37	9 44	9 51	9 57	10 4	10 11
17	9 38	9 45	9 52	9 59	10 20	10 13	10 20	10 28	10 33	10 42	10 49
18	10 12	10 19	10 27	10 34	10 42	10 49	10 57	11 4	11 12	11 19	11 27
19	10 46	10 54	11 5	11 10	11 18	11 26	11 34	11 41	11 49	11 57	12 5
20	11 29	11 38	11 37	11 24	11 8	12 2	12 10	12 18	12 17	12 35	12 42
21	11 58	12 3	12 11	12 20	12 9	12 38	12 40	12 55	13 4	13 13	13 21
22	12 28	12 37	12 46	12 55	13 5	13 14	13 23	13 33	13 41	13 50	13 50
23	13 2	13 12	13 21	13 31	13 43	13 59	13 59	14 9	14 10	14 28	14 38
24	13 36	13 46	13 56	14 6	14 16	14 26	14 36	14 46	14 56	15 6	15 16

The moon's path may be reprefented on the globe in a very pleafing manner, by tying a filken line over the furface of the globe, exactly on the ecliptic; then finding, by an ephemeris, the place of the nodes for the given time, confine the filk at thefe two points, and at 90 degrees diftance from them elevate the line about 5¼ deg. from the ecliptic, and, deprefs it as much on the other, and it will then reprefent the lunar orbit for that day.

PROBLEM LXX.

To find the moon's place in the ecliptic, for any given hour of the day.

Firft without an ephemeris, only knowing the age of the moon, which may be obtained from every common almanack.

Elevate the north pole of the celeftial globe to 90 degrees, and then the equator will be in the plane of, and coincide with the broad paper circle; bring the firft point of Aries, marked ♈ on the globe, to the day of the new moon on the faid broad paper circle, which anfwers to the fun's place for that day; and the day of the moon's age will ftand againft the fign and degree of the moon's mean place; to which place apply a fmall patch to reprefent the moon.

But if you are provided with an ephemeris,* that will give the moon's latitude and place in the

* The nautical almanack is the beft Englifh ephemeris.

the ecliptic; firſt note her place in the ecliptic upon the globe, and then counting ſo many degrees amongſt the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or ſouth upon the given day, and that will be the point which repreſents the true place of the moon for that time, to which apply the artificial ſun, or a ſmall patch.

Thus on the 11th of May, 1787, ſhe was at noon in 2 deg. 35 min. of Piſces, and her latitude was 4 deg. 18 min.; but as her diurnal motion for that day is 12 48 in nine hours, ſhe will have paſſed over 4 deg. 47 min. which added to her place at noon, gives 7 h. 22 min. for her place on the 11th of May, at nine at night.

PROBLEM LXXI.

To find the moon's declination for any given day or hour.

The place in her orbit being found, by prob. lxx. bring it to the brazen meridian; then the arch of the meridian contained between it and the equinoctial, will be the declination ſought.

PROBLEM LXXII.

To find the moon's greateſt and leaſt meridian altitudes in any given latitude, that of London for example.

It

It is evident, this can happen only when the aſcending node of the moon is in the vernal equinox; for then her greateſt meridian altitude will be 5 deg. greater than that of the ſun, and therefore about 67 deg.; alſo her leaſt meridian altitude will be 5 deg. leſs than that of the ſun, and therefore only 10 deg.: there will therefore be 57. deg. difference in the meridian altitude of the moon; whereas that of the ſun is but 47 deg.

N. B. When the ſame aſcending node is in the autumnal equinox, then will her meridian altitude differ by only 37 deg.; but this phænomenon can ſeparately happen but once in the revolution of a node, or once in the ſpace of nineteen years: and it will be a pleaſant entertainment to place the ſilken line to croſs the ecliptic in the equinoctial points alternately; for then the reaſon will more evidently appear, why you obſerve the moon ſometimes within 23 deg. of our zenith, and at other times not more than 10 deg. above the horizon, when ſhe is full ſouth.

PROBLEM LXXIII.

To illuſtrate, by the globe, the phænomenon of the harveſt moon.

About the time of the autumnal equinox, when the moon is at or near the full, ſhe is obſerved to riſe almoſt at the ſame time for ſeveral nights

nights together; and this phænomenon is called the HARVEST MOON.

This circumſtance, with which farmers were better acquainted than aſtronomers, till within theſe few years, they gratefully aſcribed to the goodneſs of God, not doubting that he had ordered it on purpoſe to give them an immediate ſupply of moon-light after ſun-ſet, for their greater convenience in reaping the fruits of the earth.

In this inſtance of the harveſt moon, as in many others diſcoverable by aſtronomy, the wiſdom and beneficence of the Deity is conſpicuous, who really ſo ordered the courſe of the moon, as to beſtow more or leſs light on all parts of the earth, as their ſeveral circumſtances and ſeaſons render it more or leſs ſerviceable.*

About the equator, where there is no variety of ſeaſons, moon-light is not neceſſary for gathering in the produce of the ground; and there the moon riſes about 50 minutes later every day or night than on the former. At conſiderable diſtances from the equator, where the weather and ſeaſons are more uncertain, the autumnal full moons riſe at ſun-ſet from the firſt to the third quarter. At the poles, where the ſun is for half a year abſent, the winter full moons ſhine con-

* Ferguſon's Aſtronomy.

conſtantly without ſetting, from the firſt to the third quarter.

But this obſervation is ſtill further confirmed, when we conſider that this appearance is only peculiar with reſpect to the full moon, from which only the farmer can derive any advantage; for in every other month, as well as the three autumnal ones, the moon, for ſeveral days together, will vary the time of it's riſing very little; but then in the autumnal months this happens about the time when the moon is at the full; in the vernal months, about the time of new moon; in the winter months, about the time of the firſt quarter; and in the ſummer months, about the time of the laſt quarter.

Theſe phænomena depend upon the different angles made by the horizon, and different parts of the moon's orbit, and that the moon can be full but once or twice in a year, in thoſe parts of her orbit which riſe with the leaſt angles.

The moon's motion is ſo nearly in the ecliptic, that we may conſider her at preſent as moving in it.

The different parts of the ecliptic, on account of it's obliquity to the earth's axis, make very different angles with the horizon as they riſe or ſet. Thoſe parts, or ſigns, which riſe with the ſmalleſt angles, ſet with the greateſt, and vice verſa. In equal times, whenever this angle

angle is leaſt, a greater portion of the ecliptic riſes, than when the angle is larger.

This may be ſeen, by elevating the globe to any conſiderable latitude, and then turning it round it's axis in the horizon.

When the moon, therefore, is in thoſe ſigns which riſe or ſet with the ſmalleſt angles, ſhe will riſe or ſet with the leaſt difference of time, and with the greateſt difference in thoſe ſigns which riſe or ſet with the greateſt angles.

Thus in the latitude of London, at the time of the vernal equinox, when the ſun is ſetting in the weſtern part of the horizon, the ecliptic then makes an angle of 62 deg. with the horizon; but when the ſun is in the autumnal equinox, and ſetting in the ſame weſtern part of the horizon, the ecliptic makes an angle but of 15 deg. with the horizon; all which is evident by a bare inſpection of the globe only.

Again, according to the greater or leſs inclination of the ecliptic to the horizon, ſo a greater or leſs degree of motion of the globe about it's axis will be neceſſary to cauſe the ſame arch of the ecliptic to paſs through the horizon; and conſequently the time of it's paſſage will be greater or leſs, in the ſame proportion; but this will be beſt illuſtrated by an example.

Therefore, ſuppoſe the ſun in the vernal equinox,

nox, rectify the globe for the latitude of London, and place of the ſun; then bring the vernal equinox, or ſun's place, to the weſtern edge of the horizon, and the hour index will point precisely to VI; at which time, we will alſo ſuppoſe the moon to be in the autumnal equinox, and conſequently at full, and riſing exactly at the time of ſun-ſet.

But on the following day, the ſun, being advanced ſcarcely one degree in the ecliptic, will ſet again very nearly at the ſame time as before: but the moon will, at a mean rate, in the ſpace of one day, paſs over 13 deg. in her orbit; and therefore, when the ſun ſets in the evening after the equinox, the moon will be below the horizon, and the globe muſt be turned about till 13 deg. of Libra come up to the edge of the horizon, and then the index will point to 7 h. 16 min. the time of the moon's riſing, which is an hour and $\frac{1}{4}$ after ſun-ſet for dark night. The next day following, there will be $2\frac{1}{2}$ hours, and ſo on ſucceſſively, with an increaſe of $1\frac{1}{4}$ h. dark night each evening reſpectively, at this ſeaſon of the year; all owing to the very great angle which the ecliptic makes with the horizon at the time of the moon's riſing.

On the other hand, ſuppoſe the ſun in the autumnal equinox, or beginning of Libra, and the moon oppoſite to it in the vernal equinox, then

then the globe (rectified as before) being turned about till the ſun's place comes to the weſtern edge of the horizon, the index will point to VI, for the time of his ſetting, and the riſing of the full moon on that equinoctial day. On the following day, the ſun will ſet nearly at the ſame time; but the moon being advanced (in the 24 hours) 13 deg. in the ecliptic, the globe muſt be turned about till that arch of the ecliptic ſhall aſcend the horizon, which motion of the globe will be very little, as the ecliptic now makes ſo ſmall an angle with the horizon, as is evident by the index, which now points to VI h. 17 deg. for the time of the moon's riſing on the ſecond day, which is about ¼ of an hour after ſun-ſet. The third day, the moon will riſe within ½ an hour; on the forth, within ¾ of an hour, and ſo on; ſo that it will be near a week before the nights will be an hour without illumination; and in greater latitudes, this difference will be ſtill greater, as you will eaſily find by varying the caſe, in the practice of this celebrated problem, on the globe.

This phænomenon varies in different years; the moon's orbit being inclined to the ecliptic about 5 degrees, and the line of the nodes continually moving retrograde, the inclination of her orbit to the equator will be greater at ſome ſeaſons than it is at others, which prevents her haſtening to the northward, or deſcend-

ing

ing ſouthward, in each revolution, with an equal pace.

Of the Tides.

A tide is that motion of the water in the ſea and rivers, by which they are found regularly to riſe and fall.

The general cauſe of the tides was diſcovered by Sir Iſaac Newton, and are deduced from the following conſiderations.

We find, by conſtant experience, that all bodies fall down to the earth's ſurface in perpendicular lines; and as lines perpendicular to the ſurface of a ſphere, tend towards the center, therefore the lines, along which all heavy bodies fall, are directed towards the earth's center.

As theſe bodies apparently fall by their weight or gravity, the law by which they fall is called the law of gravitation.

Now as bodies, by their gravity, fall towards the earth, it has not been deemed improper to ſay, that the earth attracts thoſe bodies, and therefore, in reſpect to the earth, the word GRAVITATION and ATTRACTION may be uſed one for the other, as by them is meant no more than the power, or law, by which bodies tend towards it's center.

Sir Iſaac Newton, by a ſagacity peculiar to himſelf, diſcovered from many obſervations, that this law of gravitation or attraction was

universally diffused throughout the solar system, and that the regular motions observed among the heavenly bodies, were governed by the same principle; so that the earth and moon attracted each other, and were both of them attracted by the sun. Also, that the force of attraction, exerted by these bodies one on the other, was less as the distance increased, in proportion to the squares of those distances.

It is not in the motion of the celestial bodies only, that the effects of this mutual gravitation are visible; we are now to explain, by the same principle, a phænomenon which passes upon the earth, the ebbing and flowing of the sea.

As the earth is attracted by the sun and moon, the parts of the earth will not gravitate towards it's center in the same manner as if those parts were not affected by such attractions.

It is also very evident, that if the earth was entirely free from these actions of the sun and moon, the oceans would then be equally attracted towards it's center, on all sides, by the force of gravity, and would continue in perfect stagnation, without ever ebbing or flowing.

But as the ocean is not free from these actions, it must needs rise higher in those places where the sun and moon diminish it's gravity, or where the sun and moon have the greatest attraction.

As the force of gravity will be moſt diminiſhed in thoſe parts of the earth where her attraction is moſt powerful, (which muſt be when ſhe is neareſt to, or in the zenith of thoſe places,) the waters in thoſe parts will riſe higheſt, and it will be FULL SEA, or FLOOD, in ſuch places.

The parts of the earth directly under the moon, and thoſe alſo in their nadir, or ſuch places as are diametrically oppoſite to thoſe where the moon is in the zenith, will have the flood, or high water, at the ſame time.

For either hemiſphere of the earth would gravitate equally towards the other half, were they free from all external attraction.

But by the action of the moon, the gravitation of one hemiſphere towards the center is diminiſhed, and that of the other is increaſed.

Now in the hemiſphere next the moon, the parts in the zenith being moſt attracted, and thereby their gravitation towards the earth's center diminiſhed; conſequently, the waters in thoſe parts muſt be higher than in any other of this hemiſphere.

But in the hemiſphere which is moſt remote from the moon, the nadir, or moſt diſtant point, being leſs attracted by the moon than thoſe parts that are nearer, is left as it were behind, while all the other parts, and even the center itſelf,

itſelf, is more attracted towards her, and conſequently the water will be higher in that point than at any other part of this hemiſphere.

The two middle points will therefore be higheſt in their reſpective hemiſpheres; the one being rally more ELEVATED, the other leſs DEPRESSED by the moon's attraction, than the adjacent parts.

Thoſe parts of the earth where the moon appears in the horizon, or is 90 degrees diſtant from the zenith and nadir, will have the ebbs or loweſt waters.

For as the waters in the zenith and nadir riſe at the ſame time, the waters in their neighbourhood will preſs towards thoſe places, to maintain the equilibrium; and to ſupply the place of theſe, others will move the ſame way, and ſo on to places at 90 degrees diſtant from the zenith and nadir; conſequently, in thoſe places where the moon appears in the horizon, the waters will have more liberty to deſcend towards the center, and therefore in thoſe places they will be the loweſt.

Hence it plainly follows, that if the ſurface of the earth was covered with water, it would put on a ſpheroidal, or egg-like figure, whoſe longeſt diameter would paſs through the place where the moon is vertical, and the ſhorteſt diameter will be where ſhe is in the horizon;

and as the moon apparently ſhifted her poſition from eaſt to weſt, in going round the earth every day, the longer diameter of the ſpheroid would follow her motion, and thus occaſion the two floods and ebbs obſervable in about every 25 hours, which is about the length of a lunar day.

Hence in any place, the greater the moon's mid-day altitude, the greater the evening tides will be; and the greater the midnight depreſſion, the greater the tides will be.

The ſummer evening and the winter morning tides are higheſt, becauſe the moon's ſummer altitude, and winter depreſſion, are greateſt, eſpecially when her declination is north in ſummer, and ſouth in winter.

The time of high water is not preciſely at the time of the moon's coming to the meridian, but about an hour or two after.

For the moon acts with ſome force after ſhe has paſt the meridian, and thereby adds to the libration, or waving motion, which ſhe has put the water into, whilſt ſhe was in the meridian, in the ſame manner as a ſmall force applied upwards to a ball already raiſed to ſome height, will raiſe it ſtill higher.

The

The tides are greater than ordinary twice every month, that is, about the times of new and full moon; they are called SPRING TIDES.

For at thefe times the actions of both fun and moon concur to draw in the fame right line; and therefore the fea muft be moft elevated. In conjunction, or when the fun and moon are on the fame fide of the earth, they both confpire to raife the water in the zenith, and confequently in the nadir. And when the fun and moon are in oppofition, that is, when the earth is between them, whilft one makes high water in the zenith and nadir, the other does the fame in the nadir and zenith.

The tides are lefs than ordinary twice every month, that is, about the times of the firft and laft quarters of the moon; and thefe are called NEAP TIDES.

Becaufe in thefe quarters of the moon, the fun raifes the waters where the moon depreffes it; and depreffes where the moon raifes; fo that the tides are made only by the difference of their actions.

It is to be obferved, that the fpring tides do not happen directly on the new and full moons, but rather a day or two after, when the action of the fun and moon have confpired together for a

confiderable time. In like manner, the neap tides happen a day or two after the quarters.

When the moon is in her perigæum, or neareft approach to the earth, the tides increafe more in the fame circumftances than at other times.

The fpring tides are greateft about the times of the equinoxes, that is, about the latter end of March and September, than at any other times of the year, and the neap tides are the lefs.

Becaufe the longer diameter of the fpheroid will at that time be in the earth's equator, and confequently defcribe a great circle of the earth, by whofe diurnal rotation the floods will move fwifter, as defcribing a great circle in the fame time they ufed to defcribe a leffer circle, by which means the waters will be thrown more forcibly againft the fhores, and muft rife higher.

The circumftances hitherto explained, would always take place, if the whole furface of the earth was covered with fea; but fince it is not fo, there arife a great many different appearances, which require particular folutions, in which the fituation of the fhores, &c. muft be confidered; for thefe, we muft refer the reader to larger works on aftronomy.

Small inland feas, fuch as the Mediterranean and the Baltic, are but little fubject to tides; be-

caufe

caufe the action of the fun and moon is nearly equal at both extremities. In very high latitudes the tides are alfo very inconfiderable; for the fun and moon always acting near the equator, and raifing the water towards the torrid zone, the neighbourhood of the poles muft be confequently deprived of thofe waters, and the fea muft be low, relative to other parts.

PROBLEM LXXIV.

To find what azimuth the moon is upon at any place when it is flood, or high water; and thence the high tide for any day of the moon's age at the fame place.

Having obferved the hour and minute of high water, about the time of new or full moon, rectify the globe to the latitude and fun's place; find the moon's place and latitude in an ephemeris, to which fet the artificial moon,* and fcrew the quadrant of altitude in the zenith; turn the globe till the horary index points to the time of flood, and lay the quadrant over the center of the artificial moon, and it will cut the horizon in the point of the compafs upon which the moon was, and the degrees on the horizon contained between the ftrong brafs meridian and the quadrant, will be the moon's azimuth from the fouth.

* Or patch reprefenting the moon.

To find the time of high water at the ſame place.

Rectify the globe to the latitude and zenith, find the moon's place by an ephemeris for the given day of her age, or day of the month, and ſet the artificial moon to that place in the zodiac; put the quadrant of altitude to the azimuth before found, and turn the globe till the artificial moon is under it's graduated edge, and the horary index will point to the time of the day on which it will be high water.

The Use of the Celestial Globe in the Solution of Problems ascertaining the Places and visible Motions or Orbits of Comets.*

There is another claſs, or ſpecies of planets, which are called COMETS. Theſe move round the ſun in regular and ſtated periods of times, in the ſame manner, and from the ſame cauſe, as the reſt of the planets do; that is, by a centripetal force, every where decreaſing as the ſquares of the diſtances increaſe, which is the general law of the whole planetary ſyſtem. But this centripetal force in the comets being compounded with the projectile force, in a very different ratio from that which is found in the planets, cauſes their orbits to be much more ellip-

* Martin's Deſcription and Uſe of the Globes.

elliptical than thofe of the planets, which are almoft circular.

But whatever may be the form of a comet's orbit in reality, their geocentric motions, or the apparent paths which they defcribe in the heavens among the fixed ftars, will always be circular, and therefore may be fhewn upon the furface of a celeftial globe, as well as the motions and places of any of the reft of the planets.

To give an inftance of the cometary praxis on the globe, we fhall chufe that comet, for the fubject of thefe problems, which made it's appearance at Bofton, in New England, in the months of October and November, 1758, in it's return to the fun; after which, it approached fo near the fun, as to fet HELIACALLY, or to be loft in it's beams for fome time, fpent in paffing the perihelion. Then afterwards emerging from the folar rays, it appeared retrograde in it's courfe from the fun towards the latter end of March, and fo continued the whole month of April, and part of May, in the Weft Indies, particularly in Jamaica, whofe latitude rendered it vifible in thofe parts, when it was, for the greateft part of the time, invifible to us, by reafon of it's fouthern courfe through the heavens.

When two obfervations can be made of a comet, it will be very eafy to affign it's courfe, or

or mark it out upon the ſurface of the celeſtial globe. Theſe, with regard to the above-mentioned comet, we have, and they are ſufficient for our purpoſe in regard to the ſolution of cometary problems.

By an obſervation made at Jamaica on the 31ſt of March, 1759, at V o'clock in the morning, the comet's altitude was found to be 22 deg. 50 min. and it's azimuth 71 deg. ſouth-eaſt. From hence we ſhall find it's place on the ſurface of the globe, by the following problem.

PROBLEM LXXV.

To rectify the globe for the latitude of the place of obſervation in Jamaica, latitude 17 deg. 30 min. and given day of the month, viz. March 31ſt.

Elevate the north pole to 17 deg. 30 min. above the horizon, then fix the quadrant of altitude to the ſame degree in the meridian, or zenith-point. Again, the ſun's place for the 31ſt of March is in 10 deg. 34 min. ♈, which bring to the meridian, and ſet the hour index at XII, and the globe is then rectified for the place and time of obſervation.

PROBLEM LXXVI.

To determine the place of a comet on the ſurface of the celeſtial globe from it's given altitude,

tude, azimuth, hour of the day, and latitude of the place.

The globe being rectified to the given latitude, and day of the month, turn it about towards the eaſt, till the hour index points to the given time, viz. V o'clock in the morning; then bring the quadrant of altitude to interſect the horizon in 71 deg. the given azimuth in the ſouth-eaſt quarter; then, under 22 deg. 50 min. the given altitude, you will find the comet's place, where you may put a ſmall patch to repreſent it.

PROBLEM LXXVII.

To find the latitude, longitude, declination, and right aſcenſion of the comets.

In the circles of latitude contained in the zodiac, you will find the latitude of the comet to be about 30 deg. 30 min. from the ecliptic; the ſame circle of latitude reduces it's place to the ecliptic in 26 deg. 30 min. of ♒, which i it's longitude ſought. Then bring the cometary patch to the brazen meridian, and it's declination will be ſhewn to be 9 deg. 15 min. ſouth. At the ſame time, it's right aſcenſion will be 227 deg. 30 min.

PROBELM LXXVIII.

To ſhew the time of the comet's riſing, ſouthing, ſetting, and amplitude, for the day of the obſervation at Jamaica.

Bring

Bring the place of the comet into the eaſtern ſemi-circle of the horizon, (the globe being rectified as directed) the index will point to III hours 15 min. which is the time of it's riſing in the morning at Jamaica, the amplitude 10 deg. very nearly to the ſouth. The patch being broght to the meridian, the index points to IX o'clock 10 min. for the time of culminating, or being ſouth to them. Laſtly, bring the patch to touch the weſtern meridian, and the index will point to III in the afternoon, for the time of the comet's ſetting, with 10 deg. of ſouthern amplitude, of courſe.

PROBLEM LXXIX.

From the comet's place being given to find the time of it's riſing in the horizon of London, on the 31ſt day of March, 1759.

For this purpoſe, you need only rectify the globe for the given latitude of London, and bring the cometary patch to the eaſtern horizon, and the index points to III hours, 45 min. for the time of it's riſing at London, with about 14 deg. of ſouth amplitude; then turn the patch to the weſtern horizon, and the index points to II h. 25 min. the time of it's ſetting.

N. B. From hence it appears, the comet roſe ſoon enough that morning to have been obſerved at London, had the heavens been clear, and the

aſtrono-

aſtronomers been before-hand apprized of ſuch a phænomenon.

PROBLEM LXXX.

To determine another place of the ſame comet, from an obſervation made at London on the 6th day of May, at X in the evening.

On the 6th day of May, 1759, at X at night, the place of the comet was obſerved, and it's diſtance meaſured with a micrometer, from two fixed ſtars marked μ and ν in the conſtellation called HYDRA, and it's altitude was found to be 16 deg. and it's azimuth 37 deg. ſouth-weſt, from whence it's place on the ſurface of the globe is exactly determined, as in prob. lxxvi. and having ſtuck a patch thereon, you will have the two places of the comet on the ſurface of the globe, for the two diſtant days and places of obſervation, as required.

PROBLEM LXXXI.

From two given places of a comet, to aſſign it's apparent path among the fixed ſtars in the heavens.

The two places of the comet being determined by the obſervations on the 31ſt of March, 1758, and the 6th of May following, and denoted by two patches reſpectively, you muſt move the globe up and down, in the notches of the horizon, till ſuch time you bring both the

patches

patches to coincide with the horizon; then will the arch of the horizon between the two patches ſhew, upon the celeſtial globe, the apparent place of the comet in the interval between the two obſervations, and by drawing a line with a black lead pencil along by the frame of the horizon, it's path on the ſurface of the globe will be delineated, as required. And here it may be obſerved, that it's apparent path lay through the following ſouthern conſtellations, viz. the tail of Capricorn, the tail of Piſces Auſtralis, by the head of Indus, the neck and body of Pavo, through the neck of Apus, below Triangulum Auſtrale, above Muſca, by the lowermoſt of the Croſiers, acroſs the hind legs and through the tail of Centaurus, from thence between the two ſtars in the back of the Hydra before-mentioned; after this, it paſſed on to Sextans Uraniæ, and then to the ecliptic near Cor Leonis; ſoon after which, it totally diſappeared.

PROBLEM LXXXII.

To eſtimate the apparent velocity of a comet, two places thereof being given by obſervation.

Let one place be aſcertained near the beginning of it's appearance, and the other towards the end thereof; then bring theſe two places to the horizon, and count the number of degrees interſected between them, which being the ſpace apparently deſcribed in a given time, will be the

velocity required. Thus, in the caſe of the above-mentioned comet, you will find, that it deſcribed more than 150 deg. in the ſpace of 36 days, which is more than 4 deg. per day.

PROBLEM LXXXIII.

To repreſent the general phænomena of the comet, for any given latitude.

Bring the viſible path of the comet to coincide with the horizon, by which it was drawn, and then obſerve what degree of the meridian is in the north point of the horizon, which, in the caſe of the foregoing comet, will be the 23 deg. This will ſhew the greateſt latitude in which the whole path can be viſible in any latitude leſs than this, as that of Jamaica; where, for inſtance, the moſt ſouthern part of the path will be elevated more than 5 deg. above the horizon, and the comet viſible through the whole time of it's apparition. But rectifying the globe for the latitude of London, the path of the ſaid comet will be for the moſt part inviſible, or below the horizon; and therefore it could not have been ſeen in our latitude, but at times very near the beginning and end of it's appearance; becauſe, by bringing the comet's path on one part to the ſouth point of the horizon, it will immediately appear in what part the comet ceaſes to be viſible; and then bringing the other part of the path

to

to the point, it will appear in what part it will again become viſible.

After this manner may the problems relating to any other comets be performed; and thus the paths of the ſeveral comets, which have hitherto been obſerved, may be ſeverally delineated on the celeſtial globe, and their various phænomena in different latitudes be thereby ſhewn.

The Use of the Celestial Globe, in Problems relative to the fixed Stars.

The uſe of the celeſtial globe is in no inſtance more conſpicuous, than in the problems concerning the fixed ſtars. Among many other advantages, it will, if joined with obſervations on the ſtars themſelves, render the practice and theory of other problems eaſy and clear to the pupil, and vaſtly facilitate his progreſs in aſtronomical knowledge.

The heavens are as much ſtudded over with ſtars in the day, as in the night; only that they are then rendered inviſible to us, by the brightneſs of the ſolar rays. But when this glorious luminary deſcends below the horizon, they begin gradually to appear. When the ſun is about 12 degrees below the horizon, ſtars of the firſt magnitude become viſible: when he is 13 degrees, thoſe of the ſecond are ſeen: when 14 degrees, ſtars of the third magnitude appear: when 15 degrees, thoſe of the fourth preſent themſelves

themſelves to view: when he is deſcended about 18 degrees, the ſtars of the fifth and ſixth magnitude, and thoſe that are ſtill ſmaller, become conſpicuous, and the azure arch ſparkles with all it's glory.

PROBLEM LXXXIV.

To find the right aſcenſion and declination of any given ſtar.

Bring the given ſtar to the meridian, and the degree under which it lies is it's declination; and the point in which the meridian interſects the equinoctial is it's right aſcenſion. For inſtance, let Arcturus be the given ſtar; this brought to the meridian will be ſeen under the 20 deg. 20 min. which is therefore it's declination, north; and it's right aſcenſion is, at the ſame time, ſhewn in the equinoctial to be 211 deg. Again, another inſtance may be Sirius, the dog-ſtar, which, brought to the meridian, will be ſeen under the 16 deg. 30 min. which is his declination, ſouth; and it's right aſcenſion 98 deg. 20 min. in the equinoctial line.

PROBLEM LXXXV.

To find the latitude and longitude of a given ſtar.

Bring the pole of the ecliptic to the meridian, over which fix the quadrant of altitude, and holding the globe very ſteady, move the qua-

drant to lie over the given ſtar, and it will cut that degree in the edge, as will ſhew it's latitude from the ecliptic, and in the ecliptic the quadrant will cut that degree which is called it's place REDUCED TO THE ECLIPTIC, or longitude from the beginning of Aries. Thus, with reſpect to Arcturus, it's latitude from the ecliptic will be found 30 deg. 30 min. and it's longitude in the ecliptic about 20 deg. 20 min. of Libra. This problem regards either pole, as the ſtars are in the northern or ſouthern hemiſpheres, reſpectively.

PROBLEM LXXXVI.

The right aſcenſion and declination of a ſtar being given, to find it's place on the globe.

Turn the globe till the meridian cuts the equinoctial in the degree of right aſcenſion. Thus, for example, ſuppoſe the right aſcenſion of Aldebaran to be 65 deg. 30 min. and it's declination to be 16 deg. north, then turn the globe about till the meridian cuts the equinoctial in 65 deg. 30 min. and under the 16 deg. of the meridian, on the northern part, you will obſerve the ſtar Aldebaran, or the bull's eye.

PROBLEM LXXXVII.

To find the time of the riſing, ſouthing, ſetting, amplitude, &c. of any ſtar, in a given latitude and day of the year.

The

The precept is the ſame as in the problems for the ſun. Thus, let it be required to know at what time the Pleiades (or ſeven ſtars) riſe, ſet, &c. in the latitude of London, on the 11th of May. The globe being rectified for the latitude of London, and the ſun's place for the given day, turn the globe about till you bring the Pleiades into the eaſtern ſemi-circle of the horizon, and the index will point to 34 deg. 45 min. the time of their riſing in the morning. Then bring the ſaid cluſter of ſtars to the meridian, and the index will point to about ½ after XII for the time of their culminating, or being upon the meridian. Laſtly, bring them into the weſtern horizon, and the index will point to VIII 40 min. which ſhews the time of their ſetting in the evening of that day. It will alſo appear, on the circle of the horizon, that they riſe with about 40 deg. of amplitude to the north, and ſet with the ſame amplitude from the weſt.

PROBLEM LXXXVIII.

To find what conſtellation any remarkable ſtar, ſeen in the firmament, belongs to.

Bring the ſun's place in the ecliptic for that day to the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated; the celeſtial globe being rectified to the latitude, turn the globe till it points to the preſent hour; and by the help of the mariner's compaſs, and

attending to the variation, which at London is nearly 24 degrees from the north, weſtward, ſet the north pole of the globe towards the north pole of the heavens.

The ſtar upon the globe (if you conceive yourſelf in the center) which directs towards that point in the heavens, in which the ſtar you want to know is ſeen, is the ſtar required.

At the ſame time, by comparing the ſtars in the heavens with thoſe upon the globe, the other ſtars and their conſtellations may be eaſily known; whereby you will be enabled, any ſtar-light night, to point out many of thoſe ſtars called correſpondents to various places on the earth.

PROBLEM LXXXIX.

To find at what hour any known ſtar paſſes the meridian on any day in the year.

Rectify the globe to the latitude, and ſet the artificial ſun to his place in the ecliptic; bring it's center under the ſtrong braſs meridian, and ſet the horary index to XII; then turn the globe till the ſtar comes to the meridian, and the horary index will point upon the equator to the hour on which that ſtar will be upon the ſouth part of the meridian.

If you turn the globe on till the center of the artificial ſun is under that graduated ſide of the braſs meridian, which is below the elevated pole,

pole, all thofe ftars, which are then cut by that fide of the meridian above the faid pole, will pafs the meridian at midnight.

PROBLEM XC.

To find on what day of the year any ftar paffes the meridian at any propofed hour of the night.

Bring the ftar to the ftrong brafs meridian, and fet the horary index to the propofed hour; then turn the globe till the index points to XII, and that degree on the ecliptic, which is cut by the meridian, is the fun's place, againft which, in the calendar upon the broad paper circle, is the day of the month.

PROBLEM XCI.

To trace the circles of the fphere in the ftarry firmament.

We fhall folve this problem for the time of the autumnal equinox; becaufe that interfection of the equator and ecliptic will be directly under the depreffed part of the meridian about midnight; and then the oppofite interfection will be elevated above the horizon; and alfo becaufe our firft meridian upon the terreftrial globe paffing through London, and the firft point of Aries, when both globes are rectified to the latitude of London, and to the fun's place, and the firft point of Aries is brought under the graduated fide of each of their meridians, we fhall have

the correſponding face of the heavens and the earth repreſented, as they are with reſpect to each other at that time, and the principal circles of each ſphere will correſpond with each other.

The horizon is then diſtinguiſhed, if we begin from the north and count weſtward, by the following conſtellations; the hounds and waiſt of Bootes, the northern crown, the head of Hercules, the ſhoulders of Serpentarius, and Sobieſki's ſhield; it paſſes a little below the feet of Antinous, and through thoſe of Capricorn, through the Sculptor's frame, Eridanus, the ſtar Rigell in Orion's foot, the head of Monoceros, the crab, the head of the little lion, and lower part of the great bear.

The meridian is then repreſented by the equinoctial colure, which paſſes through the ſtar marked δ in the tail of the little bear, under the north pole, the pole ſtar, one of the ſtars in the back of Caſſiopea's chair marked β, the head of Andromeda, the bright ſtar in the wing of Pegaſus marked γ, and the extremity of the tail of the whale.

That part of the equator which is then above the horizon, is diſtinguiſhed on the weſtern ſide by the northern part of Sobieſki's ſhield, the ſhoulder of Antinous, the head and veſſel of Aquarius, the belly of the weſtern fiſh in Piſces; it paſſes through the head of the whale, and a

bright ſtar marked δ in the corner of his mouth, and thence through the ſtar marked δ in the belt of Orion, at that time near the eaſtern ſide of the horizon.

That half of the ecliptic which is then above the horizon, if we begin from the weſtern ſide, preſents to our view Capricornus, Aquarius, Piſces, Aries, Taurus, Gemini, and a part of the conſtellation Cancer.

The ſolſtitial colure, from the weſtern ſide, paſſes through Cerberus, and the hand of Hercules, thence by the weſtern ſide of the conſtellation Lyra, and through the dragon's head and body, through the pole point under the polar ſtar, to the eaſt of Auriga, through the ſtar marked η in the foot of Caſtor, and through the hand and elbow of Orion.

The northern polar circle, from that part of the meridian under the elevated pole, advancing towards the weſt, paſſes through the ſhoulder of the great bear, thence a little to the north of the ſtar marked α in the dragon's tail, the great knot of the dragon, the middle of the body of Cepheus, the northern part of Caſſiopea, and baſe of her throne, through Camelopardalus, and the head of the great bear.

The tropic of Cancer, from the weſtern edge of the horizon, paſſes under the arm of Hercules, under the vulture, through the gooſe and fox, which is under the beak and wing of the ſwan,

under the ſtar called Sheat, marked β in Pegaſus, under the head of Andromeda, and through the ſtar marked φ in the fiſh of the conſtellation Piſces, above the bright ſtar in the head of the ram marked α, through the Pleiades, between the horns of the bull, and through a group of ſtars at the foot of Caſtor, thence above a ſtar marked δ, between Caſtor and Pollux, and ſo through a part of the conſtellation Cancer, where it diſappears by paſſing under the eaſtern part of the horizon.

The tropic of Capricorn, from the weſtern ſide of the horizon, paſſes through the belly, and under the tail of Capricorn, thence under Aquarius, through a ſtar in Eridanus marked c, thence under the belly of the whale, through the baſe of the chemical furnace, whence it goes under the hare at the feet of Orion, being there depreſſed under the horizon.

The ſouthern polar circle is inviſible to the inhabitants of London, by being under our horizon.

Arctic and antarctic circles, or circles of perpetual apparition and occultation.

The largeſt parallel of latitude on the terreſtrial globe, as well as the largeſt circle of declination on the celeſtial, that appears entire above the horizon of any place in north latitude, was

5. called

called by the ancients the arctic circle, or circle of perpetual apparition.

Between the arctic circle and the north pole in the celestial sphere, are contained all those stars which never set at that place, and seem to us, by the rotative motion of the earth, to be perpetually carried round above our horizon, in circles parallel to the equator.

The largest parallel of latitude on the terrestrial, and the largest parallel of declination on the celestial globe, which is entirely hid below the horizon of any place, was by the ancients called the antarctic circle, or circle of perpetual occultation.

This circle includes all the stars which never rise in that place to an inhabitant of the northern hemisphere, but are perpetually below the horizon.

All arctic circles touch their horizons in the north point, and all antarctic circles touch their horizons in the south point; which point, in the terrestrial and celestial spheres, is the intersection of the meridian and horizon.

If the elevation of the pole be 45 degrees, the most elevated part either of the arctic or antarctic circle, will be in the zenith of the place.

If the pole's elevation be less than 45 degrees, the zenith point of those places will fall without it's arctic or antarctic circle; if greater, it will fall within.

Therefore,

Therefore, the nearer any place is to the equator, the leſſer will it's arctic and antarctic circles be; and on the contrary, the farther any place is from the equator, the greater they are. So that,

At the poles, the equator may be conſidered as both an arctic and antarctic circle, becauſe it's plane is coincident with that of the horizon.

But at the equator (that is, in a right ſphere) there is neither arctic nor antarctic circle.

They who live under the northern polar circle, have the tropic of Cancer for their arctic, and that of Capricorn for their antarctic circle.

And they who live on either tropic, have one of the polar circles for their arctic, and the other for their antarctic circle.

Hence, whether theſe circles fall within or without the tropics, their diſtance from the zenith of any place is ever equal to the difference between the pole's elevation, and that of the equator above the horizon of that place.

From what has been ſaid, it is plain there may be as many arctic and antarctic circles, as there are individual points upon any one meridian, between the north and ſouth poles of the earth.

Many authors have miſtaken theſe mutable circles, and have given their names to the immutable polar circles, which laſt are arctic and

an-

antarctic circles, in one particular caſe only, as has been ſhewn.

PROBLEM XCII.

To find the circle, or parallel of perpetual apparition, or occultation of a fixed ſtar in a given latitude.

By rectifying the globe to the latitude of the place, and turning it round on it's axis, it will be immediately evident, that the circle of perpetual apparition is that parallel of declination which is equal to the complement of the given latitude northward; and for the perpetual occultation, it is the ſame parallel ſouthward, that is to ſay, in other words, all thoſe ſtars, whoſe declinations exceed the co-latitude, will always be viſible, or above the horizon; and all thoſe in the oppoſite hemiſphere, whoſe declination exceeds the co-latitude, never riſe above the horizon.

For inſtance; in the latitude of London 51 deg. 30 min. whoſe co-latitude is 38 deg. 30 min. gives the parallels deſired; for all thoſe ſtars which are within the circle, towards the north pole, never deſcend below our horizon; and all thoſe ſtars which are within the ſame circle, about the ſouth pole, can never be ſeen in the latitude of London, as they never aſcend above it's horizon.

PROBLEM

PROBLEM XCIII.

To represent the face of the heavens on the globe for a given hour on any day of the year.

Rectify the globe to the given latitude of the place and day of the month, setting it due north and south by the needle; then turn the globe on it's axis till the index points to the given hour of the night; then all the upper hemisphere of the globe will represent the visible face of the heavens for that time, by which it will be easily seen what constellations and stars of note are then above our horizon, and what position they have with respect to the points of the compass. In this case, supposing the eye was placed in the center of the globe, and holes were pierced through the centers of the stars on it's surface, the eye would perceive through those holes the various corresponding stars in the firmament; and hence it would be easy to know the various constellations at sight, and to be able to call all the stars by their names.

The use of this problem is most extensive, as it acquaints us at any time with the apparent face or state of the heavens, and shews us when the moon, or any of the planets, may be seen, or fit for examination by the telescope. We can also from hence learn, when any of those curious and wonderful objects, called NEBULOUS

STARS, may be seen, and which strike the mind of the observer with amazement, by presenting to his view an indefinite number of the smallest fixed stars through the whole field of view in his telescope.

From hence also, the position of that very extraordinary phænomenon called the GALAXY, or MILKY WAY, is at any time known.

This single problem, therefore, may be considered in itself as sufficient to recommend the use of the celestial globe to every studious and rational mind, as the most necessary instrument of his celestial tuition.

PROBLEM XCIV.

The latitude of the place, the sun's place, and the hour of the night being given, to find the azimuth and altitude of any known fixed star.

Rectify the globe for the latitude of the place, and the sun's place; turn the globe till the hour index points to the given hour; then fix the quadrant of altitude in the zenith, and lay it over the star, and it will shew the altitude and azimuth of it.

It was by observing the times of the risings and settings of the fixed stars, or the times of their culminating or passing the meridian, that the

the ancients determined the hour or time of night.

PROBLEM XCV.

The latitude of the place, the ſun's place, and the azimuth of any known ſtar being given, to find the hour of the night.

Having rectified the globe for the latitude of the place and the ſun's place, if the given ſtar be due north or ſouth, bring it to the meridian, and the index will ſhew the hour of the night.

If the ſtar be in any other direction, fix the quadrant of altitude in the zenith, and ſet it to the ſtar's azimuth in the horizon; turn the globe about until the quadrant cuts the center of the ſtar, and then the horary index will ſhew the hour of the night.

But as it may poſſibly happen that we may ſee a ſtar, and would be glad to know what ſtar it is, or whether it may not be a new ſtar, or a comet; how that may be diſcovered, will be ſeen under the following

PROBLEM XCVI.

The latitude of the place, the ſun's place, the hour of the night, and the altitude and azimuth of any ſtar being given, to find the ſtar.

Rectify

Rectify the globe for the latitude of the place, and the ſun's place; fix the quadrant of altitude in the zenith, and turn the globe till the hour index points to the given hour, and ſet the quadrant of altitude to the given azimuth; then the ſtar that cuts the quadrant in the given altitude, will be the ſtar ſought.

Though two ſtars, that have different right aſcenſions, will not come to the meridian at the ſame time, yet it is poſſible that in a certain latitude they may come to the ſame vertical circle at the ſame time; and that conſideration gives the following

PROBLEM XCVII.

The latitude of the place, the ſun's place, and two ſtars, that have the ſame azimuth, being given, to find the hour of the night.

Rectify the globe for the latitude, the zenith, and the ſun's place; then turn the globe, and alſo the quadrant about, till both the ſtars coincide with it's edge; the hour index will ſhew the hour of the night, and the place where the quadrant cuts the horizon, will be the common azimuth of both ſtars.

What hath been obſerved above, of two ſtars that have the ſame azimuth, will hold good likewiſe of two ſtars that have the ſame altitude; from whence we have the following

PROBLEM

PROBLEM XCVIII.

The latitude of the place, the ſun's place, and two ſtars, that have the ſame altitude, being given, to find the hour of the night.

Rectify the globe for the latitude of the place, the zenith, and the ſun's place; turn the globe, ſo that the ſame degree on the quadrant ſhall cut both ſtars, then the hour index will ſhew the hour of the night.

In the former propoſitions the latitude of the place is ſuppoſed to be given, or known. But as it is frequently neceſſary to find the latitude of the place, and eſpecially at ſea, how this may be found, in a rude manner at leaſt, having the time given by a good clock, or watch, will be ſeen in the following

PROBLEM XCIX.

The ſun's place, the hour of the night, and two ſtars, that have the ſame azimuth, or altitude, being given, to find the latitude of the place.

Rectify the globe for the ſun's place, and turn it, till the index points to the given hour of the night; keep the globe from turning, and move it up and down in the notches, till the two given ſtars have the ſame azimuth, or altitude; then the braſs meridian will ſhew the height

height of the pole, and consequently the latitude of the place.

PROBLEM C.

Two ſtars being given, one on the meridian, and the other on the eaſt and weſt part of the horizon, to find the latitude of the place.

Bring the ſtar obſerved on the meridian to the meridian of the globe; then keeping the globe from turning round it's axis, ſlide the meridian up or down in the notches, till the other ſtar is brought to the eaſt or weſt part of the horizon; and that elevation of the pole will be the latitude of the place ſought.

OBSERVATION.

From what hath been ſaid, it appears, that if, of theſe five things, 1. the latitude of the place; 2. the ſun's place in the ecliptic; 3. the hour of the night; 4. the common azimuth of two known fixed ſtars; 5. the equal altitude of two known fixed ſtars; any THREE of them being given, the remaining TWO will eaſily be found.

There are three ſorts of riſings and ſettings of the fixed ſtars, taken notice of by ancient authors, and commonly called POETICAL RISINGS and SETTINGS, becauſe moſtly taken notice of by the poets.

Theſe are the COSMICAL, ACHRONICAL, and HELIACAL.*

They are to be found in moſt authors that treat on the doctrine of the ſphere, and are now chiefly uſeful in comparing and underſtanding paſſages in the ancient writers; ſuch are Heſiod, Virgil, Columella, Ovid, Pliny, &c. How they are to be found by calculation, may be ſeen in Petavius's Uranologion, and Dr. Gregory's aſtronomy.

DEFINITION.

When a ſtar riſes or ſets at ſun-riſing, it is ſaid to riſe or ſet COSMICALLY.

From whence we ſhall have the following

PROBLEM CI.

The latitude of the place being given, to find, by the globe, the time of the year when a given ſtar riſes or ſets coſmically.

Let the given place be Rome, whoſe latitude is 42 deg. 8 min. north; and let the given ſtar be the Lucida Pleiadum. Rectify the globe for the latitude of the place; bring the ſtar to the edge of the eaſtern horizon, and mark the point of the ecliptic riſing along with it; that will be found to be Taurus, 18 deg. oppoſite to which, on the horizon, will be found May the 8th. The

* Coſtard's Hiſtory of Aſtronomy.

The Lucida Pleiadum, therefore, rifes cofmically May the 8th.

If the globe continues rectified as before, and the Lucida Pleiadum be brought to the edge of the weftern horizon, the point of the ecliptic, which is the fun's place, then rifing on the eaftern fide of the horizon, will be Scorpio, 29 deg. oppofite to which, on the horizon, will be found November the 21ft. The Lucida Pleiadum, therefore, fets cofmically November the 21ft.

In the fame manner, in the latitude of London, Sirius will be found to rife cofmically Aug. the 10th, and to fet cofmically Nov. 10th.

It is of the cofmical fetting of the Pleiades, that Virgil is to be underftood in this line,

ANTE TIBI EOÆ ATLANTIDES ABSCONDANTUR,*

and not of their SETTING IN THE EAST, as fome have imagined, where ftars rife, but never fet.

DEFINITION.

When a ftar rifes or fets at fun-fetting, it is faid to rife or fet ACHRONICALLY.

Hence, likewife, we have the following

PROBLEM CII.

The latitude of the place being given, to find the time of the year when a given ftar will rife or fet achronically.

* Georg. l. 1, v. 221.

Let the given place be Athens, whoſe latitude is 37 deg. north, and let the given ſtar be Arcturus.

Rectify the globe for the latitude of the place, and bringing Arcturus to the eaſtern ſide of the horizon, mark the point of the ecliptic then ſetting on the weſtern ſide; that will be found Aries, 12 deg. oppoſite to which, on the horizon, will be found April the 2d. Therefore, Arcturus riſes at Athens achronically April the 2d.

It is of this riſing of Arcturus that Heſiod ſpeaks in his Opera & Dies.*

When from the ſolſtice ſixty wintry days
Their turns have finiſh'd, mark with glitt'ring
  rays,
From ocean's ſacred flood ARCTURUS riſe,
Then firſt to gild the duſky evening ſkies.

If the globe continues rectified to the latitude of the place, as before, and Arcturus be brought to the weſtern ſide of the horizon, the point of the ecliptic ſetting along with it will be Sagittary, 7 deg. oppoſite to which, on the horizon, will be found November the 29th. At Athens, therefore, Arcturus ſets achronically November the 29th.

In the ſame manner Aldebaran, or the bull's eye, will be found to riſe achronically May the 22d, and to ſet achronically December the 19th.

DEFINITION.

* Lib. ii. ver. 285.

DEFINITION.

When a ſtar firſt becomes viſible in the morning, after it hath been ſo near the ſun as to be hid by the ſplendor of his rays, it is ſaid to riſe HELIACALLY.

But for this there is required ſome certain depreſſion of the ſun below the horizon, more or leſs according to the magnitude of the ſtar. A ſtar of the firſt magnitude is commonly ſuppoſed to require that the ſun be depreſſed 12 deg. perpendicularly below the horizon.

This being premiſed, we have the following

PROBLEM CIII.

The latitude of the place being given, to find the time of the year when a given ſtar will riſe heliacally.

Let the given place be Rome, whoſe latitude is 42 deg. north, and let the given ſtar be the bright ſtar in the bull's horn.

Rectify the globe for the latitude of the place, ſcrew on the braſs quadrant of altitude in it's zenith, and turn it to the weſtern ſide of the horizon. Bring the ſtar to the eaſtern ſide of the horizon, and mark what degree of the ecliptic is cut by 12 deg. marked on the quadrant of altitude; that will be found to be Capricon, 3 deg. the point oppoſite to which is Cancer, 3 deg. and oppoſite to this will be found, on the hori-

zon, June 25th. The bright ſtar, therefore, in the bull's horn, in the latitude of Rome, riſes heliacally June the 25th.

Theſe kinds of riſings and ſettings are not only mentioned by the poets, but likewiſe by the ancient phyſicians and hiſtorians.

Thus Hippocrates, in his book De Ære, ſays, "one ought to obſerve the heliacal riſings and ſettings of the ſtars, eſpecially the Dog star, and Arcturus; likewiſe the cosmical ſetting of the Pleiades."

And Polybius, ſpeaking of the loſs of the Roman fleet, in the firſt Punic war, ſays, "it was not ſo much owing to fortune, as to the obſtinacy of the conſuls, in not hearkening to their pilots, who diſſuaded them from putting to ſea at that ſeaſon of the year, which was between the riſing of Orion and the Dog star; it being always dangerous, and ſubject to ſtorms."*

DEFINITION.

When a ſtar is firſt immerſed in the evening, or hid by the ſun's rays, it is ſaid to ſet heliacally.

And this again is ſaid to be, when a ſtar of the firſt magnitude comes within 12 degrees of the ſun, reckoned in the perpendicular.

Hence again we have the following

PROBLEM

* Lib. 1. p. 53.

PROBLEM CIV.

The latitude of the place being given, to find the time of the year when a given ſtar ſets heliacally.

Let the given place be Rome, in latitude 42 deg. north, and let the given ſtar be the bright ſtar in the bull's horn. Rectify the globe for the latitude of the place, and bring the ſtar to the edge of the weſtern horizon; turn the quadrant of altitude, till 12 deg. cut the ecliptic on the eaſtern ſide of the meridian. This will be found to be 7 deg of Sagittary, the point oppoſite to which, in the ecliptic, is 7 deg. of Gemini; and oppoſite to that, on the horizon, is May the 28th, the time of the year when that ſets heliacally in the latitude of Rome.

OF THE PRECESSION OF THE EQUINOX.

We have already taken notice of and illuſtrated, in page 378, that apparent ſlow motion of the fixed ſtars forwards, which is cauſed by the like ſlow motion of the equinoctial points backwards; and ſhewn that this is owing to the revolution of the axis of the equator about the axis of the ecliptic, the pole of the equator deſcribing in the heavens a circle about the axis of the ecliptic. By this motion they are found to recede from their ancient ſtations, at the rate of 50 ſeconds

every year, making a degree in 72 years, and 25,920 years to perform one revolution.

Hence it is, that though the ſigns or conſtellations in the zodiac are called by the ſame names with thoſe in the ecliptic, yet the ſigns in one do not anſwer to thoſe in the other; the ſign called Aries, for inſtance, in the ecliptic, is not in that part of it which anſwers to the figure or conſtellation of Aries in the zodiac: the ſame is equally true of all the other ſigns. This is made very plain upon the celeſtial globe; for the reader will find there that the mark ♈ and the 30 deg. reckoned from it, which make the ſign Aries in the ecliptic, are not within the figure or conſtellation of the ram. This motion in their longitude does not, however, vary their latitude.

Hence their places being once determined to a known year, their longitudes may be aſcertained for any time paſt or to come, by the ſole ſubtraction or addition of ſo many times 50 ſeconds, as there are years between that to which the given ſtar is rectified, and that to which it is required; or knowing the quantity of preceſſion from any former period, the diſtance thereof in time may be obtained, by reducing it into ſeconds, and dividing the reſult by 50, the quotient will give the number of years, as in the following examples.

EXAMPLE I.

Given, 1908 years. To find the quantity of the preceſſion for that time.

$$\begin{array}{ll} & 1908 \text{ years} \\ \text{Multiply by} & -\ 50 \text{ ſeconds} \\ \hline & 60)\ 95400 \\ \hline & 60)\ 1590 \\ \hline \end{array}$$

Anſwer - - 26° 30 preceſſion in 1908 years.

EXAMPLE II.

Given 26° 30′ the quantity of the preceſſion, to find the time.

$$\begin{array}{ll} & 26^\circ\ 30' \\ \text{Multiply by} & 60 \\ \hline & 1590 \text{ minutes} \\ \text{Multiply by} & 60 \\ \hline \text{Divide by } 50) & 95400 \text{ ſeconds} \\ \hline \end{array}$$

Anſwer - 1908 years.

The regular change in the preceſſion of the fixed ſtars or rather the conſtant retrogreſſion of the equinoctial points, ſeems to cauſe an irregular variation in their right aſcenſions and declinations

tions, more or lefs, according to their diftances from the pole of the ecliptic. Whence it may not be improper to fhew how thefe may be found, as the cofmical, achronical, and heliacal rifings and fettings of the fixed ftars, found by the preceding problems, have refpect only to the prefent age; and the following problem will fhew the reader how to determine the ancient place of any ftar agreeable to the time of ancient authors, if their authority may be depended on.

PROBLEM CV.

Given the latitude and ancient longitude of a fixed ftar, to find it's right afcenfion and declination.

Elevate the celeftial globe to 66½ degrees, bring the pole of the ecliptic into the zenith, and there fix the quadrant of altitude; apply it's graduated edge to the given ftar, and it will cut it's prefent longitude, either on the ecliptic or broad paper circle, which in this pofition of the globe coincide with each other: make a mark on the quadrant, at the latitude of the given ftar, and remove it to it's ancient longitude, as found above; then bring the graduated edge of the moveable meridian to the mark juft made upon the quadrant of altitude, and fet the center of the artificial fun to that point which will then reprefent the ancient place of the given ftar. That point of the moveable meridian, upon which the center

center of the artificial ſun was placed, is it's ancient declination; and that point of the equator, cut by it's graduated edge, is it's ancient right aſcenſion.

The globe being thus rectified to the place and preceſſion of any particular ſtar, as given us by ancient authors, the times of the year when ſuch ſtar roſe or ſet, either coſmically, achronically, or heliacally, may be thus obtained by the preceding problems, agreeable to the period of the author under conſideration. The reader, who wiſhes to purſue this ſubject farther, will find it illuſtrated by many curious and learned examples in the Rev. Mr. Coſtard's Hiſtory of Aſtronomy.

Of the Correspondence of the Celestial and Terrestrial Spheres.*

That the reader may thoroughly underſtand what is meant by the correſpondence between the two ſpheres, let him imagine the celeſtial globe to be delineated upon glaſs, or any other tranſparent matter, which ſhall inveſt or ſurround the terreſtrial globe, but in ſuch a manner, that either may be turned about upon the poles of the globe, while the other remains fixed; and ſuppoſe the firſt point of Aries on the inveſting globe to be placed upon the firſt point of Aries on the terreſtrial globe, (which point is in the meridian of London) then every ſtar in the celeſtial ſphere

* Adams's Treatiſe on the Globes.

ſphere will be directly over thoſe places, to which it is a correſpondent. Each ſtar will then have the degree of it's right aſcenſion directly upon the correſponding degree of terreſtrial longitude; their declination will alſo be the ſame with the latitude of the places to which they anſwer; or in other words, when the declination of a ſtar is equal to the latitude of a place, ſuch ſtar, within the ſpace of 24 hours, will paſs vertically over that place, and all others that have the ſame latitude.

If we conceive the celeſtial inveſting globe to be fixed, and the terreſtrial globe to be gradually turned from weſt to eaſt, it is clear, that as the meridian of London paſſes from one degree to another, under the inveſting ſphere, every ſtar in the celeſtial ſphere becomes correſpondent to another place upon the earth, and ſo on, until the earth has completed one diurnal revolution; or till all the ſtars, by their apparent daily motion, have paſſed over every meridian of the terreſtrial globe. From this view of the ſubject, an amazing variety, uniting in wonderful and aſtoniſhing harmony, preſents itſelf to the attentive reader; and future ages will find it difficult to inveſtigate the reaſons that ſhould induce the preſent race of aſtronomers to neglect a ſubject ſo highly intereſting to ſcience, even in a practical view, but which in theory would lead

them

them into more ſublime ſpeculations, than any that ever yet preſented themſelves to their minds.

A GENERAL DESCRIPTION OF THE PASSAGE OF THE STAR MARKED γ IN THE HEAD OF THE CONSTELLATION DRACO, OVER THE PARALLEL OF LONDON.

The ſtar γ, in the head of the conſtellation Draco, having 51 deg. 32 min. north declination, equal to the latitude of London, is the correſpondent ſtar thereto. To find the places which it paſſes over, bring London to the graduated ſide of the braſs meridian, and you will find that the degree of the meridian over London and the repreſentative of the ſtar, paſſes over from London, the road to Briſtol, croſſes the Severn, the Briſtol channel, the counties of Cork and Kerry in Ireland, the north part of the Atlantic ocean, the Streights of Belleiſle, New Britain, the north part of the province of Canada, New South Wales, the ſouthern part of Kamſchatka, thence over different Tartarian nations, ſeveral provinces of Ruſſia, over Poland, part of Germany, the ſouthern part of the United Provinces, when croſſing the ſea, it arrives again at the meridian of London.

When the ſaid ſtar, or any other ſtar, is on the meridian of London, or any other meridian, all other ſtars, according to their declination and right aſcenſion, and difference of right aſcen-
ſion

ſion, (which anſwers to terreſtrial latitude, longitude, and difference of longitude) will at the ſame time be on ſuch meridians, and vertical to ſuch places as correſpond in latitude, longitude, and difference of longitude, with the declination, &c. of the reſpective ſtars.*

From the ſtars, therefore, thus conſidered, we attain a copious field of geographical knowledge, and may gain a clear idea of the proportionable diſtances, and real bearings, of remote empires, kingdoms, and provinces, from our own zenith, at the ſame inſtant of time; which may be found in the ſame manner as we found the place to which the ſun was vertical at any propoſed time.

Many inſtances of this mode of attaining geographical knowledge, may be found in my father's treatiſe on the globes.

We cannot conclude this eſſay on the celeſtial globe, better than with the Rev. Mr. Woolaſton's remarks at the end of his "PREFACE TO A SPECIMEN OF A GENERAL ASTRONOMICAL CATALOGUE," after exhorting all of every nation, and climate, to unite in one common endeavour to perfect our catalogues of the fixed ſtars, and render the knowledge of aſtronomy as extenſive, as the art and induſtry of man can make it.

"Neither ought that, ſays he, to be eſteemed a fruitleſs inquiry, or matter of bare ſpeculation.

To

* Fairman's Geography.

To what ufes fuch knowledge may be turned, what new fcenes may hereafter open to our view, it is impoffible to guefs. Though enough is already known to be of great fervice in common life, and at the fame time to awaken contemplation; yet the ftrides that have been made of late years in every branch of philofophy, and not the leaft in this, cannot but move an inquifitive mind to a defire of farther knowledge, which may lead on to farther benefit. The more the heavenly bodies excite our aftonifhment, from their fize, their diftances, the regularity of their motions, or any peculiarity or perfection we difcover in thofe attractions by which they feem retained in their places, the more clear it is to any reafoning head that they could not have made themfelves: and that clofe connection between caufe and effect, which the farther we fearch the more clearly we difcern, though it has ftaggered the faith of many a celebrated naturalift, is itfelf a proof, if he had not ftopped fhort of the conclufion, that all thefe muft have been the contrivance of confummate wifdom, and guided by an unerring hand.

Yet at the fame time he who fees that every little corner on this earth of our's is replete with animal life, though but one race on it feems to be endowed with reafoning faculties, cannot but be led on to a conjecture at leaft, that all thofe vaft bodies he difcovers in the heavens may be

peopled

peopled with their gradations of inhabitants likewise; and that each of them not improbably contains it's rational beings too, to acknowledge and adore the Creator of them all. So far the heathen philosopher may go: though, if he be a modest inquirer after truth, he will not dogmatize, or enter into any particular detail of what is so totally out of his reach.

But the christian may perhaps allow himself, not to dogmatize on his part, but to carry his conjectures a few steps farther. Revolving in his mind what he acknowledges has been done for man, the only rational inhabitant he knows on our earth; and considering that God has sent some of his angels or messengers from time to time to declare his will to us; and has moreover sent the Christ more fully to reveal it; whatever others may think, he is satisfied thereby that however small we are in this vast universe, we are not beneath the notice of the Ruler of it. Lost in amaze at the greatness, and at the same time the goodness of the Deity towards us, will he not be led thereby into a more full acknowledgment of him, and more determined resolution of obedience to his will? This seems but the rational result from such a chain of thought.

Yet, if that thought be pursued, since the inhabitants of the other planets of our system, and of the many systems there may be among

the numberlefs ftars in the vaft expanfe, muft equally be objects of the Divine favour with ourfelves; and fince the rational inhabitants of fome few or more among fo many myriads, may have been found difobedient; is a man to blame for thinking that if they ftand in need of reftoration, they muft be full as worthy of it as ourfelves; and may, for any thing that we know, have been already redeemed, or may yet be to be redeemed, when in and what way it fhall be feen fitting by the Almighty Ruler of us all?

Such thoughts at leaft the author of thefe pages cannot but confefs have occurred to his mind while he has been contemplating the heavens, during the intervals of obfervation, till the next ftar has come into his field of view. And, though the divine fhould be cautious of bewildering others with fuch inquiries in the way of his profeffion; he trufts, that the purfuit of them impreffes on the philofopher a no lefs rational idea of the world and the inhabitants of it, than fome have, who, while they confefs the neceffity of an intelligent maker to their clocks and watches, fcornfully refufe all acknowledgment of one to the more wonderful works we behold. Neither indeed, on the other hand, does he think it tends to imprefs on any one a lefs humble notion of man's dependence upon God, than others have, who acknowledging a Creator, con-

fine all their ideas of his moral government to this little earth we inhabit.

That our earth itſelf does revolve round our ſun, together with it's other planets, is now acknowledged by all; though the time has been that ſuch acknowledgment was accounted criminal: that other planets may revolve round other ſuns, is probable: that ſome of the ſtars themſelves do move, is of late years pretty well aſcertained: that our ſun does ſo in ſome degree, is ſurmiſed from obſervation: that all the ſtars may do ſo too, is not unlikely: and if they all be thought to do ſo in any certain courſe, round one common center, on which they all depend, and by which they are all governed; it is not for man to quarrel with his brother concerning it. A conjecture it is, the idea of which has been ſtarted, and it is confeſſed is not quite diſapproved; yet is it but a conjecture at the moſt, which no man has any right to impoſe upon another, however poſſible, or however plauſible, or even convincing, it might appear to him.

But, be theſe things as they may, let each philoſopher ſearch for FACTS in every branch of ſcience; let the aſtronomer of every nation and every perſuaſion ſearch for them in his walk, and communicate his diſcoveries without reſerve; and the time may come when ſome one or more

of us ſhall find out what may yet be important to be known; one law by which they all are governed, the link in the chain of divinity as well as phyſics, by which they are connected all together."

OF THE

USE

OF THE

TERRESTRIAL GLOBE,

WHEN MOUNTED IN THE COMMON MANNER.

ALTHOUGH I have, in the firſt part of this eſſay, laid before my readers the reaſons which induce me to prefer my father's manner of mounting the globes, to the old or Ptolemaic form, yet as many may be in poſſeſſion of globes mounted in the old form, and others may have been taught by thoſe globes, I thought it would render theſe eſſays more complete, to give an account of ſo many of the leading problems, ſolved on the common globes, as would

enable them to apply the remainder of thofe heretofore folved, to their own ufe. This is the more expedient, as fince the publication of my father's treatife; there have been a few attempts to do away fome of the inconveniences of the ancient form, particularly that of the old hour circle, which is now generally placed under the meridian.

I cannot, however, refrain from again obferving to the pupil, that the folution of the problems on the old globes depends upon appearances; that therefore, if he means to content himfelf with the mere mechanical folution of them, the Ptolemaic globes will anfwer his purpofe; but if he wifhes to have clear ideas of the rationale of thofe problems, he muft ufe thofe mounted in my father's manner.

The celeftial globe is ufed the fame way in both mountings, excepting that in my father's mounting it has fome additional circles; but the difference is fo trifling, that it is prefumed the pupil can find no difficulty in applying the directions there as given to the old form.

PROBLEM I.

To find the latitude and longitude of any given place on the globe.

Bring the place to the eaft fide of the brafs meridian, then the degree marked on the meridian over it fhews it's latitude, and the degree

of

of the equator, under the meridian, ſhews it's longitude.

Hence, if the longitude and latitude of any place be given, the place is eaſily found, by bringing the given longitude to the meridian; for then the place will lie under the given degree of latitude upon the meridian.

PROBLEM II.

To find the differences of longitude between any two given places.

Bring each of the given places ſucceſſively to the brazen meridian, and ſee where the meridian cuts the equator each time; the number of degrees contained between thoſe two points, if it be leſs than 180 deg. otherwiſe the remainder to 360 deg. will be the difference of longitude required.

PROBLEM III.

To rectify the globe for the latitude, zenith, and ſun's place.

Find the latitude of the place (by prob. I.) and if the place be in the northern hemiſphere, elevate the north pole above the horizon, according to the latitude of the place. If the place be in the ſouthern hemiſphere, elevate the ſouth pole above the ſouth point of the horizon, as many degrees as are equal to the latitude.

Having elevated the globe according to it's latitude, count the degrees thereof upon the me-

ridian from the equator towards the elevated pole, and that point will be the zenith, or the vertex of the place; to this point of the meridian faſten the quadrant of altitude, ſo that the graduated edge thereof may be joined to the ſaid point.

Having brought the ſun's place in the ecliptic to the meridian, ſet the hour index at twelve at noon, and the globe will be rectified to the ſun's place.

PROBLEM IV.

The hour of the day at any place being given, to find all thoſe on the globe, where it is noon, midnight, or any given hour at that time.

On the globes when mounted in the common manner, it is now cuſtomary to place the hour circle under the north pole; it is divided into twice twelve hours, and has two rows of figures, one running from eaſt to weſt, the other from weſt to eaſt; this circle is moveable, and the meridian anſwers the purpoſe of an index.

Bring the given place to the brazen meridian, and the given hour of the day on the hour circle; this done, turn the globe about, till the meridian points at the hour deſired; then, with all thoſe under the meridian, it is noon, midnight, or any given hour at that time.

PROBLEM V.

The hour of the day at any place being given, to find the correſpondent hour (or what o'clock it is at that time) in any other place.

Bring the given place to the brazen meridian, and ſet the hour circle to the given time; then turn the globe about, until the place where the hour is required comes to the meridian, and the meridian will point out the hour of the day at that place.

Thus, when it is noon at London, it is

		H.	M.	
At	Rome - -	0	52	P. M.
	Conſtantinople	2	7	P. M.
	Vera Cruz -	5	30	A. M.
	Pekin in China -	7	50	P. M.

PROBLEM VI.

The day of the month being given, to find all thoſe places on the globe where the ſun will be vertical, or in the zenith that day.

Having found the ſun's place in the ecliptic for the given day, bring the ſame to the brazen meridian, obſerve what degree of the meridian is over it, then turn the globe round it's axis, and all places that paſs under that degree of the meridian will have the ſun vertical or in the zenith that day, i. e. directly over the head of each place at it's reſpective noon.

PROBLEM VII.

A place being given in the torrid zone, to find thofe two days of the year on which the fun will be vertical to that place.

Bring the given place to the brazen meridian, and mark the degree of latitude that is exactly over it on the meridian; then turn the globe about it's axis, and obferve the two points of the ecliptic, which pafs exactly under that degree of latitude, and look on the horizon for the two days of the year in which the fun is in thofe points or degrees of the ecliptic, and they are the days required; for on them, and none elfe, the fun's declination is equal to the latitude of the given place.

PROBLEM VIII.

To find the antœci, periœci, and antipodes of any given place.

Bring the given place to the brazen meridian, and having found it's latitude, keep the globe in that pofition, and count the fame number of degrees of latitude on the meridian, from the equator towards the contrary pole, and where the reckoning ends, that will give the place of the antœci upon the globe. Thofe who live at the equator have no antœci.

The globe remaining in the fame pofition, bring the upper XII on the horary circle to the meridian,

meridian, then turn the globe about till the meridian points to the lower XII; the place which then lies under the meridian, having the ſame latitude with the given place, is the periœci required. Thoſe who live at the poles, if any, have no periœci.

As the globe now ſtands (with the index at the lower XII) the antipodes of the given place are under the ſame point of the brazen meridian where it's antœci ſtood before.

PROBLEM IX.

To find at what hour the ſun riſes and ſets any day in the year; and alſo upon what point of the compaſs.

Rectify the globe for the latitude of the place you are in; bring the ſun's place to the meridian, and bring the XII to the meridian; then turn the ſun's place to the eaſtern edge of the horizon, and the meridian will point out the hour of riſing; if you bring it to the weſtern edge of the horizon, it will ſhew the ſetting.

Thus on the 16th day of March, the ſun roſe a little paſt ſix, and ſet a little before ſix.

Note: In the ſummer the ſun riſes and ſets a little to the northward of the eaſt and weſt points, but in winter, a little to the ſouthward of them. If, therefore, when the ſun's place is brought to the eaſtern and weſtern edges of the horizon, you look on the inner circle, right againſt the ſun's place,

place, you will ſee the point of the compaſs upon which the ſun riſes and ſets that day.

PROBLEM X.

To find the length of the day and night at any time of the year.

Only double the time of the ſun's riſing that day, and it gives the length of the night; double the time of his ſetting, and it gives the length of the day.

This problem ſhews how long the ſun ſtays with us any day, and how long he is abſent from us any night.

Thus on the 26th of May the ſun riſes about four, and ſets about eight; therefore, the day is ſixteen hours long, and the night eight.

PROBLEM XI.

To find the length of the longeſt or ſhorteſt day, at any place upon the earth.

Rectify the globe for that place, bring the beginning of Cancer to the meridian; bring XII to the meridian, then bring the ſame degree of Cancer to the eaſt part of the horizon, and the meridian will ſhew the time of the ſun's riſing.

If the ſame degree be brought to the weſtern ſide, the meridian will ſhew the ſetting, which doubled (as in the laſt problem) will give the length of the longeſt day and ſhorteſt night.

If we bring the beginning of Capricorn to the

the meridian, and proceed in all reſpects as before, we ſhall have the length of the longeſt night and ſhorteſt day.

Thus in the Great Mogul's dominions, the longeſt day is 14 hours, and the ſhorteſt night 10 hours. The ſhorteſt day is 10 hours, and the longeſt night 14 hours.

At Peterſburgh, the ſeat of the Empreſs of Ruſſia, the longeſt day is about 19 $\frac{1}{2}$ hours, and the ſhorteſt night 4 $\frac{1}{2}$ hours; the ſhorteſt day 4 $\frac{1}{2}$ hours, and longeſt night 19 $\frac{1}{2}$ hours.

Note: In all places near the equator, the ſun riſes and ſets at ſix the year round. From thence to the polar circles, the days increaſe as the latitude increaſes; ſo that at thoſe circles themſelves, the longeſt day is 24 hours, and the longeſt night juſt the ſame. From the polar circles to the poles, the days continue to lengthen into weeks and months; ſo that at the very pole, the ſun ſhines for ſix months together in ſummer, and is abſent from it ſix months in winter.

Note: That when it is ſummer with the northern inhabitants, it is winter with the ſouthern, and the contrary: and every part of the world partakes of an equal ſhare of light and darkneſs.

PROBLEM XII.

To find all thoſe inhabitants to whom the ſun is this moment riſing or ſetting, in their meridian or midnight.

Find the ſun's place in the ecliptic, and raiſe the pole as much above the horizon as the ſun (that day) declines from the equator; then bring the place where the ſun is vertical at that hour to the braſs meridian; ſo will it then be in the zenith or center of the horizon. Now ſee what countries lie on the weſtern edge of the horizon, for in them the ſun is riſing; to thoſe on the eaſtern ſide he is ſetting; to thoſe under the upper part of the meridian it is noon day; and to thoſe under the lower part of it, it is midnight.

Thus on the 25th of April, at ſix o'clock in the evening, at Worceſter,

The ſun is riſing at New Zealand; and to thoſe who are ſailing in the middle of the Great South Sea.

The ſun is ſetting at Sweden, Hungary, Italy, Tunis, in the middle of Negroland and Guinea.

In the meridian (or noon) at the middle of Mexico, Bay of Honduras, middle of Florida, Canada, &c.

Midnight at the middle of Tartary, Bengal, India, and the ſeas near the Sunda iſles.

PROBLEM XIII.

To find the beginning and end of twilight.

The twilight is that faint light which opens the morning by little and little in the eaſt, before the ſun riſes; and gradually ſhuts in the evening in the weſt, after the ſun is ſet. It ariſes from the ſun's illuminating the upper part of the atmoſphere, and begins always when he approaches within 18 degrees of the eaſtern part of the horizon, and ends when he deſcends 18 degrees below the weſtern; when dark night commences, and continues till day breaks again.

To find the beginning of twilight, rectify the globe; turn the degree of the ecliptic, which is oppoſite to the ſun's place, till it is elevated 18 degrees in the quadrant of altitude above the horizon on the weſt, ſo will the index point the hour twilight begins.

This ſhort ſpecimen of problems by the old globes, it is preſumed, will be ſufficient to enable the pupil to ſolve any other.

ESSAY

ESSAY III.

CONTAINING

A DESCRIPTION

OF THE MOST IMPROVED

PLANETARIUMS, TELLURIANS,

AND

SPHERES.

IN purſuance of my original plan, I proceed to deſcribe thoſe inſtruments that have been contrived to facilitate the progreſs of aſtronomy and geography. By their aſſiſtance, the lecturer and teacher are enabled to impreſs more ſtrongly on their pupils, the principles deſigned to be cultivated. The pupil, by reſolving a problem, or explaining any particular phænomenon by an inſtrument, ſtrengthens the faculties of his mind, and realizes to himſelf by the eye and the touch, what would otherwiſe have left but a faint and imperfect trace upon his memory.

To

To repreſent by machines the motion and various aſpects of the heavenly bodies, to ſhew by them the parallelifm of the earth's axis, together with it's diurnal and annual motions; and by this means to explain the beautiful variety of the ſeaſons, and other celeſtial and terreſtrial phænomena, has ever been conſidered as one of the nobleſt efforts of mechanical genius.

It is the buſineſs of this eſſay to deſcribe the moſt modern inſtruments that have been contrived for this purpoſe. The three firſt that I ſhall deſcribe are repreſented in plate V. plate XV. and plate XVI: the one is a manual planetarium, the other a ſimple tellurian, the third a lunarium: theſe three ought to accompany every pair of globes; they are rendered as ſimple as poſſible, in order to reduce the price, that much real knowledge may be attained at an eaſy rate.

Plate XVII. fig. 1, and plate XVIII. fig. 1 and 2, repreſent what I deem to be the completeſt inſtrument of the kind: it is ſo contrived as to exhibit, with the greateſt accuracy and perſpicuity, the phænomena of the earth and heavens; being the moſt comprehenſive, and at the ſame time the leaſt defective.

Plate XIX. repreſents an elegant and neat planetarium, tellurian, and lunarium, in one inſtrument, the whole moving by wheel-work.

 Fig.

Fig. 1 and 2, plate XIII. two armillary ſpheres; a planetarium is included in that of fig. 1, plate XIII. fig. 2 is an armillary ſphere, by which the real and apparent motion of the earth and heavens may be illuſtrated and explained.

A Description of the three Instruments represented in Plate V. Plate XV. and Plate XVI.

In this part we ſhall ſuppoſe the reader to be acquainted with thoſe definitions that we have had occaſion to introduce in the preceding parts of this work; theſe being remembered, he will meet with little or no difficulty in the following pages.

Plate XV. repreſents a manual planetarium, or one in which the planets muſt be moved by hand, without the aſſiſtance of wheel-work.

First. A Description of the Planetarium, represented at Plate XV.

A planetarium may be conſidered as a diametrical ſection of our univerſe, in which the upper and lower hemiſpheres are ſuppreſſed: the ſun is repreſented by a braſs ball ⊙ placed in the center of the inſtrument; round about, but at different diſtances, the planets are placed thus on the ſtem; near the ſun is Mercury ☿, then Venus ♀, the

the Earth ⊕, Mars ♂, Jupiter ♃, and laſtly Saturn ♄.

The ſecondary ones are placed about the primary ones; thus about the earth there is one little ball to repreſent the moon, about Jupiter four, about Saturn are five beſides his ring. Upon the plate of the planetarium are placed, in two oppoſite circles, the ecliptic, and the calendar of months, by which means the planets may be ſet to their mean places in the ecliptic for any day of the year.

Imperfect as this inſtrument may appear, it will greatly aſſiſt the tutor in communicating to his pupil general ideas of the order, number, phaſes, relative poſitions, and motion of the celeſtial bodies. Either of the planets may be turned round by laying hold of, and moving the braſs bar which ſupports them. In thus imitating their different revolutions, it will be very obvious that if each of them left a trace behind of their motions, there would be ſix concentric circles deſcribed about the braſs ball repreſenting their different orbits.

A ſecond obſervation may be very properly that, which has been inſiſted on in the firſt eſſay of this work, page 16, namely, that the motions of the planets are regular and harmonious as ſeen from the ſun; the pupil, by ſuppoſing himſelf ſituated on the braſs ball, and viewing the

motion of the planets from thence, will find the idea pleafingly and fully illuftrated.

Let him afterwards fuppofe himfelf to be fituated on the earth, and he will foon find, that it is his fituation which is the fource of apparent irregularity. If he confiders the motions of the planets Venus and Mercury, he will find that in one part of their orbit, they pafs between us and the fun: this is called their inferior conjunction, while in the oppofite part they pafs on beyond, or on the other fide of the fun, which is called their fuperior conjunction.

Here alfo it becomes very evident, that neither of thefe planets can ever appear at a great diftance from the fun. The tutor may eafily explain this, and what is alfo meant by the elongation of a planet, by applying the doubled end of a piece of thread to the globe that reprefents the earth; one of the ends of the thread clofe to the ftem of the fun, and the other end to that of Venus and Mercury; he will then find on moving the planets round, that they can never appear far from the fun, and that Mercury recedes lefs from him than Venus; the angle obferved by this means would coincide exactly with that of the heavens, if the arms of the planetarium were at a fufficient length to reprefent the proportional diftances of the planets from

from each other. It is becauſe Mercury removes ſo little from the ſun, that he is ſo ſeldom ſeen.

The pupil will find that the ſuperior planets, Mars, Jupiter, or Saturn, are ſometimes ſeen in direct oppoſition to the ſun, having the earth between them and it; they are at other times ſeen in conjunction with the ſun, or on the contrary ſide of it. The phaſes of the planets are illuſtrated by placing a ſmall lamp, or piece of candle, in the center of the machine, inſtead of the braſs ball that repreſents the ſun.

The planets when moving, are continually varying their diſtances from the earth, and conſequently cannot appear to move with an uniform velocity; for they will be ſeen to move faſter when they are neareſt the earth, and ſloweſt when they are moſt remote from it; hence alſo they appear much larger at one time than at another.

The teacher may by this inſtrument make it obvious to his pupil, why the planets appear to move ſometimes direct, at others ſtationary or retrograde; by extending a ſtring from the earth over either of the planets, and to ſome diſtance beyond them, and keeping it over them during a revolution.

By the planetarium, the pupil will receive the moſt ſatisfactory evidence of the truth of the Copernican, and the errors of the Ptolemaic

ſyſtem. For on removing the braſs ball from the center, and placing in it's ſtead a ſmall ivory one to repreſent the earth, and placing a ſmall braſs ball inſtead of the ivory earth, the inſtrument will then exhibit the ſituation of the planetary bodies according to the Ptolemaic ſyſtem.

It is plain, that in this ſyſtem, in which the earth is made the center of the motion of the heavenly bodies, 1. That their motions would all have been the ſame way, or from weſt to eaſt continually; whereas in the heaven they are ſeen to move ſometimes from weſt to eaſt, at others from eaſt to weſt, while at other times they are ſtationary. 2. They would in this caſe appear to move with an uniform velocity; whereas they are always obſerved to move with a variable one. 3. On the ſuppoſition that the earth was the center of the ſyſtem, it is evident from the inſtrument, that any of the planets might be ſeen at all diſtances from the ſun, or that Mercury or Venus might be ſeen when the ſun is ſetting, not only in the ſouth, but even in the eaſt, ſituations in which they were never ſeen by any obſerver. 4. The planets Venus and Mercury being, according to this hypotheſis, within the orbit of the ſun, could never be ſeen to go behind or beyond; but from obſervation we find them as often behind as before the ſun. To remedy theſe imperfections in his ſyſtem,

and

and reconcile it with nature, Ptolemy was obliged to introduce various circles, into which he ſuppoſed the planets to deviate in their revolutions round the earth; thus multiplying cauſes without neceſſity, and rendering that perplexed, which, when rightly conſidered, is found to be ſimple.

Description of the Tellurian represented at Fig. 1, Plate V.

This is the moſt ſimple tellurian that is made; my endeavours in conſtructing it have been to form an inſtrument that ſhould render the phænomena of the ſeaſons clear to the youngeſt pupil.

It conſiſts of four ſmall globes, A, B, C, D, deſigned to repreſent our earth at the four principal ſeaſons of the year, ſummer and winter, ſpring and autumn. Theſe globes are all inclined in an angle of 66½ degrees to the plane of the ecliptic; in the center of the inſtrument a braſs ball is placed, to repreſent the ſun; there is alſo a ſmall pillar, on the top of which are placed ſeveral wires, parallel to each other, to repreſent parallel rays proceeding from the ſun; to each globe there is a black hemiſphere, placed oppoſite to the ſun, dividing the enlightened from the unenlightened parts of the globe; one of theſe black hemiſpheres may be taken off occaſionally, and the globe be removed from

it's ſituation. There is alſo a circle, which is not repreſented in the plate; this circle is placed at the height of the earth's center, and is intended to repreſent the orbit of the earth; four pieces of wire are placed at the four quarters of this circle, having the ſame inclination to it that the axis of the earth has to the plane of it's orbit, to give a clear idea of what is meant by the inclination of the axis of the earth, and what by it's paralleliſm.

To explain the required phænomena by this inſtrument, the tutor has only to aſſume two propoſitions: 1. That a globular luminous body ſending out parallel rays, will only enlighten one half of another globe, and conſequently that hemiſphere only is illuminated which is turned towards the luminous body. 2. That the globe moves round the luminous body in ſuch a manner, that in all parts of it's orbit, it's axis may be parallel to itſelf, and have a certain inclination to the plane of the orbit.

When the earth is in the firſt point of Capricorn, the ſun will appear in the firſt point of Cancer; in this ſituation, which is that of the ball A, fig. 1, plate V. the north pole is turned towards the ſun, and that part of the globe ſituated within the arctic circle, lies wholly in the enlightened hemiſphere, and has no night; while the ſouth pole, and it's polar circle, being

being totally turned from the ſun, are qu te involved in darkneſs.

In this poſition of the earth, the inhabitants of the northern hemiſphere will have their days at the longeſt, and their nights at the ſhorteſt; and the length of the longeſt days are greater, according as the place is further removed from the equator, till it reaches the polar circle, from whence to the pole there is at this ſeaſon continual day, and the ſeaſon is that of ſummer: while all the inhabitants on the ſouth ſide of the equator will have their nights the longeſt, and their days the ſhorteſt; becauſe the greateſt portion of the parallels which they deſcribe by the diurnal motion of the earth, are in darkneſs, and the leaſt in the light; the ſeaſon of the year to them at this time is winter.

To render this ſubject clearer to the pupil, let the tutor now refer him to the oppoſite ſituation of the globe at C, when the earth is in the firſt point of Cancer, and the ſun is ſeen in the firſt point of Capricon. Here the northern polar circle is all involved in darkneſs, and has no day; while the ſouthern is entirely within the light, and to the inhabitants thereof there is no night. It is now winter in the northern hemiſphere, and the days are ſhorter than the night; while in the ſouthern hemiſphere, the days are at the longeſt. If the hemiſphere be now removed from the globe which is at Capricorn, and the

globe itſelf be taken out, and brought near to that at Cancer, keeping the axis parallel to it's former ſituation, the young mind will immediately perceive how the beautiful viciſſitude in the ſeaſons is effected, merely by the inclination of the earth's axis to the plane of it's orbit, and the parallelifm of it's axis during it's annual courſe.

When the globe is at the firſt point of Aries, as at D, and the ſun appears to be in the firſt point of Libra; the circle of illumination touches both poles, and the ſun is vertical to the equator; the axis inclines ſideways to the ſun, ſo that the earth is enlightened from pole to pole, and the days and nights are equal at all places of the earth, and the ſeaſon is that of the vernal equinox.

When the earth is at Libra, the ſun appears in Aries; the earth is again enlightened from pole to pole, and the days and nights are again every where equal.

As there are 24 meridian ſemicircles drawn on each of the globes, all meeting at their poles, and as one rotation of the earth on it's axis is performed in 24 hours, each of theſe meridians is an hour diſtant from the other in every parallel of latitude. You may, therefore, find how long the day is at any place of the earth, in either of the four ſituations, by counting how many of theſe meridians are in the light in the parallel of latitude of the given place; this number being ſubtract-

ſubtracted from 24 hours, will give the length of the night.

In all poſitions of the earth, half the equator is always in the light, and half in darkneſs; therefore, at the equator the days and nights are all equal.

If you take off the cap of the globe which is moveable, then remove it from it's place, and hold it in the four cardinal ſituations in which the other are fixed, but with the axis perpendicular to the plane of the ecliptic; you will find that the ſeaſons would, in this caſe, have been always the ſame, without any alteration, and the days and nights of the ſame length at all places, throughout the whole year: only at the poles there would be hardly either day or night, the ſun, neither riſing above, nor ſetting below the horizon, but going round the ſame continually, with one half of his diſc in view. This is what would really happen, if the axis of the earth did not incline to the plane of it's orbit.

Description of the Lunarium, which is represented at Fig. 1, Plate XVI.

A B is the baſe of the inſtrument, on which there are two circles, one with the ſigns of the ecliptic, the other with the days of the month correſponding thereto, for the readier ſetting the moon or her nodes to their reſpective places. C D E F an inclined braſs plane, G H I K another

another plane parallel to the former, and supported by two braſs props; the inner edge of this ring nearly touches the artificial moon, and repreſents the plane of the moon's orbit.

The moon is ſometimes on the north ſide, and ſometimes on the ſouth ſide of the ecliptic, which is called her latitude; the degrees and parts thereof are engraved from each node to the higheſt and loweſt part of her orbit, which is 5 deg. 18 min. on each ſide of the nodes. The two nodes lie in the plane of the ecliptic, in thoſe parts of the moon's orbit where the wires that ſupport it are fixed. That from which the moon begins to aſcend northward, above the ecliptic, is called the aſcending or north node, as the oppoſite one from which the moon deſcends ſouthward, below the ecliptic, is called her deſcending node. They always keep oppoſite to each other, and move backward through all the ſigns of the ecliptic, in about nineteen years; on each ſide of them both is engraved a ſmall ſun at 18 degrees, and a ſmall moon 12 degrees diſtant from them; theſe are the limits of eclipſes, the firſt of the ſun, and the other of the moon. In uſing this inſtrument, the braſs ball repreſenting the ſun, is ſuppoſed to be on the table, oppoſite to it's place in the ecliptic, for the given time; and that the moon's nodes are alſo ſet to their place in the ecliptic.

If

If the moon's orbit coincided with the plane of the ecliptic, there would be an eclipſe of the ſun at every new moon; becauſe the moon's ſhadow then paſſing over ſome parts of the earth, would deprive them of the ſun's light; but becauſe the ſun is a great luminous body, and the moon a ſmall opake one, her ſhadow will be conical, and can only cover a ſmall part of the earth at once; and therefore there would be ſeveral ſuch eclipſes inviſible, though at noon day, to a great many places on the earth. The moon would alſo, every time ſhe was oppoſite to the ſun, paſs through the ſhadow of the earth, and undergo a total eclipſe to all thoſe inhabitants of the earth to whom it was viſible.

But as the ſun and earth are always in the plane of the ecliptic, and the moon's orbit is inclined to it, and cuts it only in the nodes, it is plain there can be no eclipſes, but when a right line paſſing through the nodes would, if continued, run either through, or nearly by the ſun, at the time of new or full moon; and from the time that this happens till it does ſo again, is about 173 days, or near half a year, ſave what allowance is to be made of 18 degrees on either ſide of the nodes, within which the ſun may be eclipſed; and of 12 degrees, within which the moon may ſuffer an eclipſe.

The foregoing circumſtances are rendered evident to the ſenſes and the mind, by means of

the lunarium; particularly ſo, when a candle, or lamp, is ſubſtituted in the place of the braſs ſun, fig. 2.

OF THE

USE AND APPLICATION

OF THE MOST IMPROVED

PLANETARIUM, LUNARIUM,

AND

TELLURIAN.

THE deſcription of the preceding inſtruments is in a great degree applicable to this improved planetarium; but as the conſtruction of this is more perfect, and as it is alſo more extenſive in it's uſe, a fuller deſcription is neceſſary, which I give the more readily, as the deſcription of this will ſerve, with very few alterations, for the greater part of orreries, &c. The explanation of the inſtrument will enable us to render ſome articles plainer, and to treat others more fully, while thoſe who have not thoroughly comprehended what has been al-

ready ſaid may gain more perfect ideas of the ſubject.

It ſeems highly probable, that the ancients were not unacquainted with planetary machines, and that the ſame powers of genius which led them to contemplate and reaſon upon the motion of the heavenly bodies, induced them to realize their ideas, and form inſtruments for explaining them; and we may fairly preſume, that theſe were carried to no ſmall degree of perfection, when we conſider that of one Archimedes was the maker, and Cicero the encomiaſt.

The inſtrument now to be deſcribed, was invented by the celebrated HUYGENS; though ſince his time it has been aſcribed to almoſt as many inventors as makers; each deviation in form, the mounting it in this mode or the other, the addition of a zodiac, or ſome ſuch ſlight changes, have been deemed by many of ſufficient importance to give them a claim to the title of inventors;—be it ſo. Let the friend of ſcience encourage every humble effort to improve it, and let him beſtow a name which, though it may in ſome meaſure gratify vanity, yet incites to labour, rather than by contempt check the ardour, or diſcourage the talents which, when called forth, may be of the greateſt ſervice to ſociety.

Description of the Planetariums.

Fig. 1, plate XVII: reprefents the planetarium, the box in which the wheel-work is contained that moves the fix primary planets round the brafs ball that reprefents the fun, in their proper periods of time, this motion being communicated to them by turning the handle.

On the upper plate of the planetarium, there are placed in two oppofite cirles, correfponding to each other, the figns of the ecliptic, and the days of the month, by means whereof the planets may be eafily fet to their mean places in the ecliptic for any day in the year. Through the center of the plate there paffes a ftrong ftem, on which the brafs ball ⊙ is placed, which reprefents the fun; round the ftem are the different fockets, which carry the arms, by which the balls reprefenting the planets are fupported. The planets are ivory balls, having the hemifphere which is next the fun white, the other black, to exhibit their refpective phafes to each other. The planets may be eafily put on or taken off their fockets, as occafion requires. About the primary planets are placed the fecondary planets, or moons, which are in this inftrument only moveable by hand; but when the inftrument is fitted upon a large fcale, and in a more expenfive form, even thefe are put in motion by the wheel-work.

The

The planets are difpofed in the following order: in the center is the brafs ball ☉ to reprefent the fun, then Mercury ☿, Venus ♀, the earth ⊕, Mars ♂, Jupiter ♃, and Saturn ♄; the Georgium Sidus is not inferted, becaufe it would not only enhance the expence, but it's motion would be fo flow, as to render it incapable of affording either amufement or inftruction. By turning the handles, the planets move about the fun from weft to eaft, with the fame relative velocities and periodical times that they have in the heavens.

When the pupil has been gratified by putting the inftrument in motion, and making his own obfervations on thofe motions, it will be proper to acquaint him with the names of the different planets, and of their divifion into primary and fecondary, to fhew him how they were firft diftinguifhed from the fixed ftars, and how the length of their periodic revolution was difcovered. Here it will be proper to obferve, that the annual motion of the earth, or the time it takes to perform it's period round the fun, is made the bafis to which the others are compared; and this is one of the reafons why the months, and days of our months, are engraved on the circle. Having obferved this, the planets may be put in motion, and they will be found to revolve round the reprefentative of the fun in their proportionable times, each planet always completing

pleting it's revolution in the ſame ſpace of time, in periods regulated and proportioned to their diſtance from the ſun: the curves which they deſcribe in their revolution, is what is termed their orbit.

Of the Distances of the Planets.

When we endeavour to form any idea of diſtance, magnitude, or duration, by numbers only, we ſo ſoon exceed the limits of conception, that we find our faculties of reaſoning as finite as our ſenſes. Hence aſtronomers are frequently obliged to have recourſe to mixed ideas, and make things of different natures and properties aſſiſt each other, to excite more adequate ideas of what they would have expreſſed. Thus,

In order to aſſiſt the imagination in forming an idea of the vaſt diſtances of the planets from the ſun, the following ſuppoſitions have been made: That if a body projected from the ſun, ſhould fly with the ſwiftneſs of a cannon ball, that is, 480 miles every hour, this body would reach the orbit of Mercury in about 8 years, 276 days; of Venus in 16 years, 136 days; of the earth in 22 years, 226 days; of Mars in 34 years, 170 days; of Jupiter in 117 years, 234 days; and the orbit of Saturn in 215 years, 286 days.

If the reader ſhould think this idea too extenſive, he may contract it in the following manner, in which the proportional bulks and

diſtances

diſtances of the ſun and planets are conſidered.

The dome of St. Paul's is 145 feet in diameter. Suppoſe a globe of this ſize to repreſent the ſun, then a globe of 9 inches will repreſent Mercury; one of 17 $\frac{2}{10}$ inches Venus; one of 18 inches the earth; one of 5 inches diameter the moon; one of 10 inches Mars; one of 15 feet Jupiter; one of 11 $\frac{1}{2}$ Saturn, with his ring 4 feet broad, and at the ſame diſtance from his body all around.

In this proportion, ſuppoſe the ſun to be at St. Paul's, Mercury might be at the Tower of London, Venus at St. James's palace, the earth at Mary-le-bone, Jupiter at Hampton-Court, and Saturn at Cliefden.

To explain, by the Planetarium, why the Sun, being a fixed Body, appears to pass through all the Signs of the Zodiac in twelve Months, or one Year. It will shew that this Phænomenon is occasioned by the annual Motion of the Earth.

As the general phænomena of the planetary ſyſtem will be beſt underſtood by an induction of particulars, I ſhould adviſe the tutor to remove all the planets but thoſe whoſe motion he is going to explain; for inſtance, let him now leave only the earth and ſun, place the earth over Libra, and it is plain that the ſun will then be

 transferred

transferred by the eye of the ſpectator to Aries, in which ſign it will appear at the latter end of March: move the earth on in it's orbit to Capricornus, and the ſun will appear at Cancer in June, ſeeming to have moved from ♈ to ♋, though it has not ſtirred, the real motion of the earth having cauſed the ſpectator to transfer the ſun to all the intermediate points in the heavens, and thus given it an apparent motion. Continue to move the earth till it arrives at Aries, and the ſun will be ſeen in Libra in the month of September: moving the earth on to Cancer, the viſual ray of the ſpectator refers the ſun to Capricorn, as it appears in the month of December. Laſtly, continue moving the earth, and it will arrive at Aries, where we ſet out. Thus we have ſhewn that it is the motion of the earth which cauſes the ſun to appear in all the different ſigns of the zodiac. Cuſtom, indeed, has taught us to ſay THE SUN IS IN ARIES, when it is between us and Aries, and ſo of any other ſign; whereas it would have been more proper to ſay, that the earth is in Libra.

To ſhew why at different times of the year we ſee the heavens decorated with an entire different collection of ſtars.

This phænomenon is occaſioned by the earth's progreſſive or annual motion; while the earth is traverſing his courſe under the vaſt concave of fixed

fixed ſtars, we are gradually carried under the different conſtellations. From hence it is evident, that at night when the earth is turned from the ſun, we ſhall in ſucceſſion have the opportunity of viewing from time to time all the ſtars in the zodiac, and conſequently a different conſtellation will preſent itſelf every month.

Thus, the Pleiades are not viſible in the ſummer; but in the winter the earth is got between the ſun and them. Theſe ſtars are obſervable at night, becauſe they are not intercepted from our ſight by the ſun's rays; and in this manner they appear during the whole winter, only they ſeem to get more weſterly every night, as the earth moves gradually by them to the eaſt. To make this ſtill more clear, place the earth in the planetarium between the ſun and any of the ſigns, that ſide towards the ſun will be day, and that towards the ſign night: it follows, that at night we are turned towards the ſtars, which in that ſign (ſuppoſe, as before, the Pleiades in Taurus) will then be conſpicuous to us; but as the ſpring approaches, the earth withdraws itſelf from between the ſun and the Pleiades, till at length the earth, by it's progreſſive motion, gets the ſun between it and the ſtars, which then lie hid behind the ſolar rays: after the ſame manner, while the earth performs his annual tract, the ſun, which always ſeems to move the contrary way, darkens, by his ſplendor, the other conſtellations

ſucceſſively; but the ſtars oppoſite to thoſe hid by the ſun, are at night preſented to our view.

General Phænomena of the Planets.

Let the tutor now place the earth, Mars, and Venus, on the planetarium, and as each planet moves with a different degree of velocity, they are continually changing their relative poſitions. Thus on turning the handle of the machine, he will find, 1ſt, that the earth moves twice as faſt as Mars, making two revolutions while he makes one; and Venus, on the other hand, moves much faſter than the earth. Secondly, that in each revolution of the earth theſe planets continually change their relative poſitions, correſponding ſometimes with the ſame point of the ecliptic, but much oftener with different points.

To explain the Conjunction, Opposition, Elongation, and other Phænomena of the inferior Planets.

We may now proceed to make ſome obſervations on the motions of Venus, as obſerved in the planetarium. If conſidered as viewed from the ſun, we ſhall find that Venus would appear at one time nearer to the earth than at another; that ſometimes ſhe would appear in the ſame part of the heavens, and at others in oppoſite parts thereof.

As

As the planets, when ſeen from the ſun, change their poſition with reſpect to the earth, ſo do they alſo, when ſeen from the earth, change their poſition with reſpect to the ſun, being ſometimes nearer to, at others farther from, and at times in conjunction with him.

But the conjunctions of Venus or Mercury, ſeen from the earth, not only happen when they are ſeen together from the ſun, but alſo when they appear to be in oppoſition to the ſolar ſpectator. To illuſtrate this, bring the earth and Venus to the firſt point of Capricorn; then by applying a ſtring from the ſun over Venus and the earth, you will find them to be in conjunction, or on the ſame point of the ecliptic.

Whereas if you turn the handle till the ſun is between Venus and the earth, a ſpectator in the ſun will ſee Venus and the earth in oppoſition; but an inhabitant of the earth will ſee Venus not in oppoſition to the ſun, but in conjunction with him.

In the firſt conjunction Venus is between the ſun and earth; this is called the inferior conjunction. In the ſecond, the ſun is ſituated between the earth and Venus; this is called the ſuperior conjunction.

After either of theſe conjunctions, Venus will be ſeen to recede daily from the ſun, but never departing beyond certain bounds, never appearing oppoſite to the ſun; and when ſhe is ſeen at

the greateſt diſtance from him, a line joining her center with the center of the earth, will be a tangent to the orbit of Venus.

To illuſtrate this, take off the ſun from it's ſupport, and the ball of Venus from it's ſupporting ſtem; place the wire, fig. 2, plate XVII. ſo that the part P may be on the ſtem that ſupports the earth, and a ſimilar ſocket, fig. 3, on the pin which ſupports the ball of Venus; the wire F is to lie in a notch at the top of the ſocket, which has been put upon the ſupporting ſtem of Venus; then will the wire repreſent a viſual ray going from an inhabitant of the earth to Venus. By turning the handle, you will now find that the planet never departs further than certain limits from the ſun, which are called it's greateſt elongations, when the wire becomes a tangent to the orbit; after which, it approaches the ſun, till it arrives at either the inferior or ſuperior conjunction.

It will alſo be evident from the inſtrument, that Venus, from her ſuperior conjunction, when ſhe is furtheſt from the earth, to the time of her inferior conjunction, when ſhe is neareſt, ſets later than the ſun, is ſeen after ſun-ſet, and is, as it were, the forerunner of night and darkneſs. But from the inferior conjunction, till ſhe comes to the ſuperior one, ſhe is always ſeen weſtward of the ſun, and muſt conſequently ſet before him in the

the evening, end rise before him in the morning, foretelling that light and day are at hand.

Bring Venus and the earth to the beginning of Aries, when they will be in conjunction; and turn the handle for nearly 225 days, and as Venus moves faster than the earth, she will be come to Aries, and have finished her course, but will not have overtaken the earth, who has moved on in the mean time; and Venus must go on for some time, in order to overtake her. Therefore, if Venus should be this day in conjunction with the sun, in the inferior part of her orbit, she will not come again to the same conjunction till after 1 year, 7 months, and 12 days.

It is also plain, by inspection of the planetarium, that though Venus does always keep nearly at the same distance from the sun, yet she is continually changing her distance from the earth; her distance is greatest when she is in her superior, and least when she is in her inferior conjunction.

To explain the Phases, the retrograde, direct, and stationary Situations of the Planets.

As Venus is an opake globe, and only shines by the light she receives from the sun, that face which is turned towards the sun will always be bright, while the opposite one will be in darkness; consequently, if the situation of the earth be such, that the dark side of Venus be turned

towards us, ſhe will then be inviſible, except ſhe appear like a ſpot on the diſk of the ſun. If her whole illuminated face is turned towards the earth, as it is in her ſuperior conjunction, ſhe appears of a circular form, and according to the different poſitions of the earth and Venus, ſhe will have different forms, and appear with different phaſes, undergoing the ſame changes of form as the moon. Theſe different phaſes are ſeen very plain in this inſtrument, as the ſide of the planet which is oppoſite to the ſun, is blackened; ſo that in any poſition, a line drawn from the earth to the planet, will repreſent that part of her diſk which is viſible to us.

The irregularities in the apparent motions of the planets, is a ſubject that this inſtrument will fully elucidate; and the pupil will find that they are only apparent, taking their riſe from the ſituation and motion of the obſerver. To illuſtrate this, let us ſuppoſe the above-mentioned wire, when connected with Venus and the earth; to be the viſual ray of an obſerver on the earth, it will then point out how the motions of Venus appear in the heavens, and the path ſhe appears to us to deſcribe among the fixed ſtars.

Let Venus be placed near her ſuperior conjunction, and the inſtrument in motion, the wire will mark out the apparent motion of Venus in the ecliptic. Thus Venus will appear to move eaſtward in the ecliptic, till the wire becomes a

tangent

tangent to the orbit of Venus, in which ſituation ſhe will appear to us to be ſtationary, or not to advance at all among the fixed ſtars; a circumſtance which is exceeding viſible and clear upon the planetarium.

Continue turning, till Venus be in her ſuperior conjunction, and you will find by the wire, or viſual ray, that ſhe now appears to move backward in the ecliptic, or from eaſt to weſt, till ſhe is arrived to that part where the viſual ray again becomes a tangent to her orbit. In which poſition, Venus will again appear ſtationary for ſome time; after which, ſhe will commence anew her direct motion.

Hence, when Venus is in the ſuperior part of her orbit, ſhe is always ſeen to move directly, according to the order of the ſigns; but when ſhe is in the inferior part, ſhe appears to move in a contrary direction.

What has been ſaid concerning the motions of Venus, is applicable to thoſe of Mercury; but the conjunctions of Mercury with the ſun, as well as the times of his being direct ſtationary or retrograde, are more frequent than thoſe of Venus.

OF THE SUPERIOR PLANETS, AS SEEN FROM THE EARTH.

If the tutor wiſhes to extend his obſervations on the inſtrument to Mars, he will find by the viſual

viſual ray, that Mars, when in conjunction, and when in oppoſition, will appear in the ſame point of the ecliptic, whether it is ſeen from the ſun or the earth; and in this ſituation only is it's real and apparent place the ſame, becauſe then only the ray proceeds as if it came from the center of the univerſe.

He will obſerve, that the direct motion of the ſuperior planets is ſwifter the nearer it is to the conjunction, and ſlower when it is nearer to quadrature with the ſun; but that the retrograde motion of a ſuperior planet is ſwifter the nearer it is to oppoſition, and ſlower the nearer it is to quadrature; but at the time of change from direct to retrograde, it's motion becomes inſenſible.

To prove by the Planetarium the Truth of the Copernican, and Absurdity of the Ptolemaic System.

Of all the prejudices which philoſophy contradicts, there is none ſo general as that the earth keeps it's place unmoved. This opinion ſeems to be univerſal, till it is corrected by inſtruction, or by philoſophical ſpeculation. Thoſe who have any tincture of education, are not now in danger of being held by it; but yet they find at firſt a reluctance to believe that there are antipodes, that the earth is ſpherical, and turns round it's axis every day, and round the ſun

every

every year. They can recollect the time when reafon ftruggled with prejudice upon thefe points, and prevailed at length, but not without fome efforts.*

The planetarium gives ocular demonftration of the motion of the earth about the fun, by fhewing that it is thus only that the celeftial phænomena can be explained, and making the abfurdity of the Ptolemaic fyftem evident to the fenfes of young people. For this purpofe, take off the brafs ball which reprefents the fun, and put on the fmall ivory ball which accompanies the inftrument in it's place, to reprefent the earth, and place a fmall brafs ball for the fun, on that arm which carries the earth.

The inftrument in this ftate will give an idea of the Ptolemaic fyftem, with the earth immoveable in the center, and the heavenly bodies revolving about in the following order: Mercury, Venus, THE SUN, Mars, Jupiter, and Saturn. Now in this difpofition of the planets, feveral circumftances are to be obferved, that are contrary to the real appearances of the celeftial motions, and which therefore prove the falfity of this fyftem.

It will appear from the inftrument, that on this hypothefis Mercury and Venus could never be feen to go behind the fun, from the earth, becaufe

* Reid's Effays on the Intellectual Powers of Man.

becaufe the orbits of both of them are contained between the fun and the earth; but thefe planets are feen to go as often behind the fun as before it; we may, therefore, from hence conclude, that this fyftem is erroneous.

It is alfo apparent in the planetarium, that on this fcheme thefe planets might be feen in conjunction with, or in oppofition to the fun, or at any diftance from it. But this is contrary to experience; for they are never feen in oppofition to the fun, or on the meridian of London, for inftance, at midnight, nor ever recede from it beyond certain limits.

Again, on the Ptolemaic fyftem all the planets would be at an equal diftance from the earth, in all parts of their orbits, and would therefore neceffarily appear always of the fame magnitude, and moving with equal and uniform velocities in one direction; circumftances which are known to be repugnant to obfervation and experience.

To rectify the planetarium, or place the planets in their true fituations, as feen from the fun.

The fituations of the planets in the heavens are accurately calculated by aftronomers, and publifhed in almanacks appropriated to the purpofe, as the nautical almanack, White's ephemeris, &c. An ephemeris is a diary or daily

 regifter

regiſter of the motions and places of the heavenly bodies, ſhewing the ſituation of each planet at 12 o'clock each day. Theſe ſituations it exhibits both as ſeen from the ſun, or from the earth; but as the former or the heliocentric is the only one of any uſe for this purpoſe, we ſhall here inſert, and explain, ſo much of that part of Mr. White's ephemeris, as will enable the pupil to rectify his planetarium.

Days.	Day increas	Length of Day	Helioc. long. ♄	Helioc. long. ♃	Helioc. long. ♂	Helioc. long. ⊖	Helioc. long. ♀	Helioc. long. ☿
1	7 4	14 48	27 ♓ 35	2 ♍ 14	27 ♍ 16	11 ♏ 14	8 ♐ 35	1 ♉ 18
7	7 24	15 8	27 47	2 42	29 57	17 2	18 7	26 ♊ 53
13	7 44	15 28	27 59	3 0	2 ♎ 39	21 52	7 37	3 ♌ 4
19	8 0	15 44	28 11	3 37	5 20	28 36	7 ♑ 7	4 ♍ 15
25	8 10	16 0	28 23	4 5	8 3	4 ♐ 22	16 36	0 ♎ 0

In the foregoing table for May, 1790, you have the heliocentric places calculated to every ſix days of the month, which is ſufficiently accurate for general purpoſes. Thus on the 19th, you have Saturn in 28° 11′ of Piſces, Jupiter 3 37′ of Virgo, Mars in 5° 20′ of Libra, the earth 28° 36′ of Virgo. Venus 7° 7′ of Capricorn, and Mercury 4° 13′ of Virgo, to which places on the ecliptic of the planetarium, the ſeveral planets are to be ſet, and they will then exhibit their real ſituations, both with reſpect to the ſun and the earth for that day.

To

To use the Instrument as a Tellurian, Plate XVIII. Fig. 1.

The ſun, the earth, and the moon, are bodies, which, from our connection with them, are ſo intereſting to us, that it is neceſſary to enter into a minute detail of their reſpective phænomena. To render this inſtrument a tellurian, all the planets are firſt to be taken off, the piece of wheel-work A B is to be placed on in their ſtead, in ſuch a manner, that the wheel c may fall into the teeth that are cut upon the edge of the ecliptic. The milled nut D is then to be ſcrewed on, to keep the wheel-work firmly in it's place. It is beſt to place this wheel-work in ſuch a manner, that the index E may point to the 21ſt of June, and then to move the globe, ſo that the north pole may be turned towards the ſun.

The inſtrument will then ſhew, in an accurate and clear manner, all the phænomena ariſing from the annual and diurnal motion of the earth; as the globe is of 3 inches diame er, all the continents, ſeas, kingdoms, &c. may be diſtinctly ſeen; the equator, the ecliptic, tropics, and other circles, are very viſible, ſo that the problems relative to peculiar places, may be ſatisfactorily ſolved. The axis of the earth is inclined to the ecliptic in an angle of 66½ degrees, and preſerves it's paralleliſm during the whole

of

of it's revolution. About the globe there is a circle, to reprefent the TERMINATOR, or boundary between light and darknefs, dividing the enlightened from the dark hemifphere. At N O is an hour circle, to determine the time of fun rifing or fetting.

The brafs index G reprefents a central folar ray; it ferves to fhew when it is noon, or when the fun is upon the meridian at any given place; it alfo fhews what fign and degree of the ecliptic on the globe the fun defcribes on any day, and the parallel it defcribes.

The plane of the terminator H I paffes through the center of the earth, and is perpendicular to the central folar ray. The index E points out the fun's place in the ecliptic of the inftrument for any given day in the year.

To explain the changes of feafons by the tellurian.

The firft thing to be done, is to rectify the tellurian; or in other words, to put the globe into a pofition fimilar to that of the earth, for any given day. Thus to rectify the tellurian for the 21ft of June, turn the handle till the annual index comes to the given day; then move the globe by the arm K L, fo that the north pole may be turned towards the fun; and adjuft the terminator, fo that it may juft touch the edge of the arctic circle. The globe is then in the fituation

tion of the earth for the longeſt day in our northern hemiſphere, the annual index pointing to the firſt point of Cancer and the 21ſt of June; bring the meridian of London to coincide with the central ſolar ray, and move the hour circle N O, till the index L points to XII; we then have the ſituation of London with reſpect to the longeſt day.

Now on gently turning the handle of the machine, the point repreſenting London will, by the rotation of the earth, be carried away towards the eaſt, while the ſun ſeems to move weſtward; and when London has arrived at the eaſtern part of the terminator, the index will point on the hour circle the time of ſun-ſetting for that day; continue to turn on, and London will move in the ſhaded part of the earth, on the other ſide of the terminator; when the index is again at XII, it is midnight at London; by moving on, London will emerge from the weſtern ſide of the terminator, and the index will point out the time of ſun-riſing, the ſun at that inſtant appearing to riſe above the horizon in the eaſt, to an inhabitant of London.

It will be evident by the inſtrument, while in this poſition, that the central ſolar ray, during the whole revolution of the earth on it's axis, only points to the tropic of Cancer, and that the ſun is vertical to no other part of the earth, but thoſe who are under this tropic.

By obſerving how the terminator cuts the ſeveral parallels of the globe, we ſhall find that all

thoſe

thoſe between the northern and ſouthern polar circles (except the equator) are divided unequally into diurnal and nocturnal arches, the former being greateſt on the north ſide of the equator, and the latter on the ſouth ſide of it.

In this poſition, the northern polar circle is wholly on that ſide the terminator which is neareſt the ſun, and therefore altogether in the enlightened hemiſphere, and the inhabitants thereof enjoy a continual day. In the ſame manner, the inhabitants of the ſouthern polar circle continue in the dark at this time, notwithſtanding the diurnal revolution of the earth; it is the annual motion only which can relieve them from this ſituation of perpetual darkneſs, and bring to them the bleſſings of day, and the enjoyments of ſummer; while in this ſtate the inhabitants in north latitude are neareſt to the central ſolar ray, and conſequently to the ſun's perpendicular beams, and of courſe a greater number of his rays will fall upon any given place, than at any other time; the ſun's rays do now alſo paſs through a leſs quantity of the atmoſphere, which, together with the length of the day, and the ſhortneſs of the night, are the reaſons of the increaſe of heat in ſummer, together with all it's other delightful effects.

While the earth continues to turn round on it's own axis once a day, it is continually advancing from weſt to eaſt, according to the

order of the ſigns, as is ſeen by the progreſs of the annual index E, which points ſucceſſively to all the ſigns and degrees of the ecliptic; the ſun in the mean time ſeems to deſcribe the ecliptic alſo, going from weſt to eaſt, at the diſtance of ſix ſigns from the earth; that is, when the earth really ſets out from the firſt point of Capricorn, the ſun ſeems to ſet out from the firſt point of Cancer, as is plain from the index.

But as during the annual revolution of the earth, the axis always remains parallel to itſelf, the ſituation of this axis, with reſpect to the ſun, muſt be continually changing.

As the earth moves on in the ecliptic, the northern polar circle gets gradually under the terminator, ſo that when the earth is arrived at the firſt point of Aries, and the annual index is at the firſt point of Libra on the 22d of September, this circle is divided into two equal parts by the terminator, as is alſo every other parallel circle, and conſequently the diurnal and nocturnal arches are equal; this is called the time of equinox, the days and nights are then equal all over the earth, being each of them 12 hours long, as will be ſeen by the horary index L. The central ſolar ray G having ſucceſſively pointed to all the parallels that may be ſuppoſed to be between the equator and the tropic of Cancer, is at this period perpendicular to the inhabitants that live at the equator.

By

By continuing to turn the handle, the earth advances in the ecliptic, and the terminator ſhews how the days are continually decreaſing, and the diurnal arches ſhortening, till by degrees the whole ſpace contained by the northern polar circle is on that ſide of the terminator which is oppoſite to the ſun, which happens when the earth is got to the firſt point of Cancer, and the annual index is at the firſt point of Capricorn, on the 21ſt of December. In this ſtate of the globe, the northern polar circle, and all the country within that ſpace, have no day at all; whilſt the inhabitants that live within the ſouthern polar circle, being on that ſide of the terminator which is next the ſun, enjoy perpetual day. By this and the former ſituation of the earth, the pupil will obſerve that there are nations to whom a great portion of the year is darkneſs, who are condemned to paſs weeks and months without the benign influence of the ſolar rays. The central ſolar ray is now perpendicular to the tropic of Capricorn; the length of the days is inverſly what it was when the ſun entered Cancer, the days being now at their ſhorteſt, and the nights longeſt in the northern hemiſphere the length of each is pointed out by the horary index.

The earth being again carried on till it enters Libra, and the ſun Aries, we ſhall again have all the phænomena of the equinoctial ſea-

ſons. The terminator will divide all the parallels into two equal parts; the poles will again be in the plane of the terminator, and conſequently as the globe revolves, every place from pole to pole will deſcribe an equal arch in the enlightened and obſcure hemiſpheres, entering into and going out of each exactly at ſix o'clock, as ſhewn by the hour index.

As the earth advances, more of the northern polar circle comes into the illuminated hemiſphere, and conſequently the days increaſe with us, while thoſe on the other ſide of the equator decreaſe, till the earth arrives at the firſt point of Capricorn, the place from which we firſt began to make our obſervations.

To explain the phænomena, that take place in a parallel, direct, and right ſphere.

Take off the globe and it's terminator, and put on in it's place the globe which accompanies the inſtrument, and which is furniſhed with a meridian, horizon, and quadrant of altitude; the edge of the horizon is graduated from the eaſt and weſt, to the north and ſouth points, and within theſe diviſions are the points of the compaſs. to the under ſide of this horizon; but at 18 degrees from it another circle is affixed, to repreſent the twilight circle; the meridian is graduated like the meridian of a globe; the quadrant of altitude is divided into

into degrees, beginning at the zenith, and finishing at the horizon.

This globe, if the horizon be differently ſet with reſpect to the ſolar ray, will exhibit the various phænomena ariſing from the ſituation of the horizon with reſpect to the ſun, either in a right, a parallel, or an oblique ſphere; or having ſet the horizon to any place, you will ſee by the central ſolar ray how long the ſun is above or below the horizon of that place, and at what point of the compaſs he riſes, his meridian altitude, and many other curious particulars, of which we ſhall give a few examples.

Set the horizon to coincide with the equator, and place the earth in the firſt point of Libra; then will the globe be in the poſition of a parallel ſphere, and of the inhabitants of the poles at that ſeaſon of the year, which inhabitants are repreſented by the pin at the upper part of the quadrant of altitude; the handle being turned round gently, the earth will revolve upon it's axis, and the ſolar ray will coincide with the horizon, without deviating in the leaſt to the north or ſouth; ſhewing, that on the 21ſt of March the ſun does not appear to riſe or ſet to the terreſtrial poles, but paſſes round through all the points of the compaſs, the plane of the horizon biſecting the ſun's diſk.

Now place the horizon, ſo that it may coincide with the poles, and the pin repreſenting an inhabitant be over the equator, the globe in this poſition is ſaid to be in that of a right ſphere; the equator, and all the parallels of latitude, are at right angles, or perpendicular to the horizon; by turning the handle till the earth has completed a year, or one revolution about the ſun, we ſhall perceive all the ſolar phænomena as they happen to an inhabitant of the equator, which are, 1. That the ſun riſes at ſix, and ſets at ſix, throughout the year, ſo that the days and nights there are perpetually equal. 2. That on the 21ſt of March, and 22d of September, the ſun is in the zenith, or exactly over the heads of the inhabitants. 3. That one half of the year between March and September, the ſun is every day full north, and the other half between September and March, is full ſouth of the equator, his meridian altitude being never leſs than 66½ degrees.

If the pin repreſenting an inhabitant be now removed out of the equator, and ſet upon any place between it and the poles, the horizon will not then paſs through either of the poles, nor coincide with the equator, but cut it obliquely, one half being above, the other half below the horizon; the globe in this ſtate is ſaid to be in that of an oblique ſphere, of which there are as many varieties as there are places between the

equator

equator and either pole. But one example will be ſufficient; for whatever appearance happens to one place, the ſame, as to kind, happens to every other place, differing only in degree, as the latitudes differ. Bring the pin, therefore, over London, then will the horizon repreſent the horizon of London, and in one revolution of the earth round the ſun, we ſhall have all the ſolar appearances through the four ſeaſons clearly exhibited, as they really are in nature; that is, the earth ſtanding at the firſt degree of Libra, and the ſun then entering into Aries, the meridian turned to the ſolar ray, and the hour index ſet to XII, you will then have the globe ſtanding in the ſame poſition towards the ſun, as our earth does at noon on the 21ſt of March. If the handle be turned round, when the ſolar ray comes to the weſtern edge of the horizon, the hour index will point VI, which ſhews the time of ſun-ſetting; London then paſſes into, and continues in darkneſs, till the hour index having paſſed over XII hours, comes again to VI, at which time the ſolar ray gains the eaſtern edge of the horizon, thereby defining the time of ſun-riſing; ſix hours afterwards the meridian again comes to the ſolar ray, and the hour index points to XII, thereby evidently demonſtrating the equality of the day and night, when the ſun is in the equinoctial. You may then alſo

 obſerve,

obſerve, that the ſun riſes due eaſt, and ſets due weſt.

Continuing to move the handle, you will find that the ſolar ray declines from the equator towards the north, and every day at noon riſes higher upon the graduations of the meridian than it did before, continually approaching to London, the days at the ſame time growing longer and longer, and the ſun riſing and ſetting more and more towards the north, till the 21ſt of June, when the earth gets into the firſt degree of Capricorn, and the ſun appears in the tropic of Cancer, riſing about 40 minutes paſt III in the morning, and ſetting about 20 min. paſt VIII in the evening; and after continuing about ſeven hours in the nether hemiſphere, appears riſing in the north-eaſt, as before. From the 21ſt of June to the 22d of September, the ſun recedes to the ſouth, and the days gradually decreaſe to the autumnal equinox, when they again become equal.

During the three ſucceeding months, the ſun continues to decline towards the ſouth pole, till the 21ſt of December, when the ſun enters the tropic of Capricorn, riſing on the ſouth-eaſt point of the compaſs about 20 minutes paſt VIII in the morning, and ſetting about 40 minutes paſt III in the evening, at the ſouth-weſt point upon the horizon; after which, the ſun continues

in

in the dark hemiſphere for 17 hours, and then appears again in the ſouth-eaſt, as before. From this chill ſolſtice the ſun returns towards the north, and the days continually increaſe in length till the vernal equinox, when all things are reſtored in the ſame order as at the beginning.

Thus all the varieties of the ſeaſons, the time of ſun riſing and ſetting, and at what point of the compaſs; as alſo the meridian altitude and declination every day of the year, and duration of twilight, and to what place the ſun is at any time vertical, are fully exemplified by this globe and it's apparatus.

Before we quit the phænomena particularly ariſing from the motion and poſition of the earth, let the globe, with the meridian and horizon be removed, and the ivory ball which fits upon a pin be placed thereon, to repreſent the earth.

As the axis of this globe ſtands perpendicular to the plane of the ecliptic, you will find that the ſolar ray continually points to the equator of this little ball, and will never deviate to the north or ſouth; though by turning the handle, the ball is made to complete a revolution round the ſun. This ſhews that the earth in this poſition would have the days and nights equal in every part of the globe, all the year long; there would have been no difference in the climates of the earth,

no diſtinction of ſeaſons; an eternal ſummer, or never-ceaſing winter, would have been our portion; an unvaried ſameneſs that would have limited inquiry, and ſatiated curioſity; and that the variety of the ſeaſons is owing to it's axis being inclined to the plane of it's orbit.

An explanation of the cauſes of the viciſſitudes of the ſeaſons, ſo naturally introduces the following reflections of Mr. Cowper, in his Winter's Walk, that I hope they will not be deemed impertinent, either by the tutor or his pupil.

What prodigies can power divine perform
More grand than it produces year by year,
And all in ſight of inattentive man?
Familiar with th' effect we ſlight the cauſe,
And, in the conſtancy of nature's courſe,
The regular return of genial months,
And renovation of a faded world,
See nought to wonder at. Should God again,
As once in Gibeon, interrupt the race
Of the undeviating and punctual ſun,
How would the world admire! but ſpeaks it leſs
An agency divine, to make him know
His moment when to ſink, and when to riſe,
Age after age, than to arreſt his courſe?
All we behold is miracle; but ſeen
So duly, all is miracle in vain.
Where now the vital energy that mov'd,

While

While ſummer was, the pure and ſubtle
lymph
Through th' imperceptible meandring veins
Of leaf and flower? It ſleeps, and th' icy touch
Of unprolific winter has impreſſed
A cold ſtagnation on th' inteſtine tide.
But let the months go round, a few ſhort
months,
And all ſhall be reſtor'd. Theſe naked ſhoots,
Barren as lances, among which the wind
Makes wintry muſic ſighing as it goes,
Shall put their graceful foliage on again:
And more aſpiring, and with ampler ſpread,
Shall boaſt new charms, and more than they
have loſt.

* * * * * * * * * * * *

And all this uniform, uncolour'd ſcene
Shall be diſmantled of it's fleecy load,
And fluſh into variety again.
From dearth to plenty, and from death to life,
Is nature's progreſs when ſhe lectures man
In heavenly truth; evincing, as ſhe makes
The grand tranſition, that there lives and works
A ſoul in all things, and that ſoul is God.
The beauties of the wilderneſs are his,
That make ſo gay the ſolitary place,
Where no eye ſees them. And the fairer forms,
That cultivation glories in, are his.
He ſets the bright proceſſion on it's way,
And marſhals all the order of the year.

* * * * * * * * * * * *

He feeds the ſecret fire
By which the mighty proceſs is maintain'd:
Who ſleeps not, is not weary; in whoſe ſight
Slow circling ages are as tranſient days:
Whoſe work is without labour, whoſe deſigns
No flaw deforms, no difficulty thwarts;
And whoſe beneficence no change exhauſts.

Of the Lunarium, Fig. 2, Plate XVIII.

Having thus illuſtrated the phænomena, which ariſe particularly from the inclination of the earth's axis to the plane of the ecliptic, from it's rotation round it's axis, and revolution round the ſun; we now proceed to explain, by this inſtrument, the phænomena of the moon. But in order to this, it will be neceſſary to ſpeak firſt of the inſtrument, which is put in motion like the preceding one, by the teeth on the fixed wheel; it is alſo to be placed upon the ſame ſocket as the tellurian, and confined down by the ſame milled nut.

The ſloping ring P Q repreſents the plane of the moon's orbit, or path, round the earth; ſo that the moon in her revolution round the earth does not move parallel to the plane of the ecliptic, but on this inclined plane; the two points of this plane, that are connected by the braſs wire, are the nodes, one of which is marked ☊, for the aſcend-

cending node, the other ☋ for the deſcending node. The moon is therefore ſometimes on the north, and ſometimes on the ſouth ſide of the ecliptic, which deviations from the ecliptic are called her north or ſouth latitude; her greateſt deviation, which is when ſhe is at her higheſt and loweſt points, called her limits, is 5 deg. 18 min.; this, with all the other intermediate degrees of latitude, are engraved on this ring, beginning at the nodes, and numbered both ways from them. At each ſide of the nodes, and at about 18 degrees diſtant from them, we find this mark ☉, and at about 12 degrees this ☽, to indicate that when the full moon is got as far from the nodes as the mark ☽, there can be no eclipſe of the moon, nor any eclipſe of the ſun; when the new moon has paſſed the mark ☉, theſe points are generally termed the limits of eclipſes. The nodes of the moon do not remain fixed at the ſame point of the ecliptic, but have a motion contrary to the order of the ſigns.

T V is a ſmall circle parallel to the ecliptic; it is divided into 12 ſigns, and each ſign into 30 degrees; this circle is moveable in it's ſocket, and is to be ſet by hand, ſo that the ſame ſign may be oppoſite to the ſun, that is marked out by the annual index. Theſe ſigns always keep parallel to themſelves, as they go round the ſun, but the inclined plane with it's nodes go backwards,

wards, ſo that each node recedes through all the above ſigns in about 19 years. R S is a circle, on which are divided the days of the moon's age; X Y is an ellipſis, to repreſent the moon's elliptical orbit, the direct motion of the apogee, or the line of the apſides, with the ſituation of the elliptical orbit of the moon, and place of the apogee in the ecliptic at all times.

To rectify the Lunarium.

Set the annual index on the large ecliptic, to the firſt of Capricorn; then turn the plate, with the moon's ſigns upon it, until the beginning of Capricorn points directly at the ſun; turn the handle till the annual index comes to the firſt of January; then find the place of the north node in an ephemeris, to which place among the moon's ſigns, ſet the north node of her inclined orbit, by turning it till it is in it's proper place in the circle of ſigns; ſet the moon to the day of her age.

General Phænomena of the Moon.

Having rectified the lunarium for uſe, on putting it into motion it will be evident,

1. That the moon, by the mechaniſm of the inſtrument, always moves in an orbit inclined to that of the ecliptic, and conſequently in an orbit analogous to that in which the moon moves in the heavens.

2. That

2. That ſhe moves from weſt to caſt.

3. That the white or illuminated face of the moon is always turned towards the ſun.

4. That the nodes have a revolution contrary to the order of the ſigns, that is, from Aries to Piſces; that this revolution is performed in about nineteen years, as in nature.

5. That the moon's rotation upon her axis is effected and completed in about $27\frac{1}{2}$ days; whereas it is $29\frac{1}{2}$ days from one conjunction with the ſun to the next.

6. That every part of the moon is turned to the ſun, in the ſpace of her monthly or periodic revolution.

To be more particular. On turning the handle, you will obſerve another motion of the earth, which has not yet been ſpoken of, namely, it's monthly motion about the common center of gravity between the earth and moon, which center of gravity is repreſented by the pin Z. From hence we learn, that it is not the center of the earth which deſcribes what is called the annual orbit, but the center of gravity between the earth and moon, and that the earth has an irregular, vermicular, or ſpiral motion about this center, ſo that it is every month at one time nearer to, at another further from the ſun. It is evident from the inſtrument, that the moon does not regard the center of the earth, but the center of gravity as the center of her proper motion; that the

the center of the earth is furtheſt from the ſun at new moon, and neareſt at the full moon; that in the quadratures the monthly parallax of the earth is ſo ſenſible, as to require a particular equation in aſtronomical tables. Theſe particulars were firſt applied to the orrery, by the late ingenious Mr. Benjamin Martin.

To explain the Phases of the Moon.

The moon aſſumes different phaſes to us, 1. on account of her globular figure; 2. on account of the motion in her orbit, between the earth and the ſun: for whenever the moon is between the earth and the ſun, we call it new moon, the enlightened part being then turned from us; but when the earth is between the ſun and the moon, we then call it full moon, the whole of the enlightened part being then turned towards us.

The phaſes of the moon are clearly exhibited in this inſtrument; for we here ſee that half which is oppoſite to the ſun is always dark, while that which is next to the ſun is white, to repreſent the illuminated part. Thus when it is new moon, you will ſee the whole white part next the ſun, and the dark part turned towards the earth, ſhewing thereby it's diſappearance, or the time of it's conjunction and change: on turning the handle, a ſmall portion of the white part will begin to be ſeen from the earth, which portion will increaſe towards the end of the 7th day, when

when you will perceive that half of the light, and half of the dark ſide, is turned towards the earth, thus illuſtrating the appearance of the moon at the firſt quarter. From hence the light ſide will continually ſhew itſelf more and more in a gibbous form, till at the end of fourteen days the whole white ſide will be turned towards the earth, and the dark ſide from it, the earth now ſtanding in a line between the ſun and moon; and thus the inſtrument explains the oppoſition, or full moon. On turning the handle again, ſome of the ſhaded part will begin to turn towards the earth, and the white ſide to turn away from it, decreaſing in a gibbous form till the laſt quarter, when the moon will appear again as a creſcent, which ſhe preſerves till ſhe has attained another conjunction.

In this lunarium the moon has always the ſame face or ſide to the earth, as is evident from the ſpots delineated on the ſurface of the ivory ball, revolving about it's axis in the courſe of one revolution round the earth; in conſequence of which, the light and dark part of the moon appear permanent to us, and the phaſes are ſhewn as they appear in the heavens.

The tutor will be enabled by this inſtrument to explain ſome other circumſtances to his pupil; namely, that as the earth turns round it's axis once in 24 hours, it muſt in that time exhibit every part of it's ſurface to the inhabitants of the

moon, and therefore it's luminous and opake parts will be ſeen by them in conſtant rotation. As that half of the earth which is oppoſed to the ſun is always dark, the earth will exhibit the ſame phaſes to the lunarians that we do to them, only in a contrary order, that when the moon is new to us, we ſhall be full to them, and vice verſa. But as one hemiſphere only of the moon is ever turned towards us, it is only to thoſe that are in this hemiſphere who can ſee us; our earth will appear to them always in one place, or fixed in the ſame part of the heavens; the lunarians in the oppoſite hemiſphere never ſee our earth, nor do we ever view that part of the moon which they inhabit. The moon's apparent diurnal motion in the heavens is produced by the daily revolution of our earth.

If we conſider the moon with reſpect to the ſun, the inſtrument ſhews plainly that one half of her globe is always enlightened by the ſun; that every part of the lunar ball is turned to the ſun, in the ſpace of her monthly or periodical revolution, and that therefore the length of the day and night in the moon is always the ſame, and equal to 14 ¾ of our day. When the ſun ſets to the lunarians in that hemiſphere next the earth, the terreſtrial moon riſes to them, and they can therefore never have any dark night; while thoſe in the other hemiſphere can have no light by night, but what the ſtars afford.

Of

OF THE PERIODICAL AND SYNODICAL MONTH.

The difference between the periodical month, in which the moon exactly defcribes the ecliptic, and the fynodical, or time between any two new moons, is here rendered very evident. To fhew this difference, obferve at any new moon her place in the ecliptic, then turn the handle, and when the moon has got to the fame point in the ecliptic, you will fee that the dial fhews 27 $\frac{1}{3}$ days, and the moon has finifhed her periodic revolution. But the earth at the fame time having advanced in it's annual path about 27 degrees of the ecliptic, the moon will not have got round in a direct line with the fun, but will require 28 days and 4 hours more, to bring it into conjunction with the fun again.

OF ECLIPSES OF THE SUN AND MOON.

There is nothing in aftronomy more worthy of our contemplation, nor any thing more fublime in natural knowledge, than rightly to comprehend thofe fudden obfcurations of the heavenly bodies, that are termed eclipfes, and the accuracy with which they are now foretold. "One of the chief advantages derived by the prefent generation, from the improvement and diffufion of philofophy, is delivery from unneceffary terror, and exemption from falfe alarms. The unufual appearances, whether re-

gular or accidental, which once ſpread conſternation over ages of ignorance, are now the recreations of inquiſitive ſecurity. The ſun is no more lamented when it is eclipſed, than when it ſets; and meteors play their corruſcations without prognoſtic or prediction."

We have already obſerved, that the ſun is the only real luminary in the ſolar ſyſtem, and that none of the other planets emit any light but what they have received from the ſun; that the hemiſphere which is turned towards the ſun is illuminated by his rays, while the other ſide is involved in darkneſs, and projects a ſhadow, which ariſes from the luminous body.

When the ſhadow of the earth falls upon the moon, it cauſes an eclipſe of the moon; when the ſhadow of the moon falls upon the earth, it cauſes an eclipſe of the ſun.

An eclipſe of the moon, therefore, never happens but when the earth's opake body interpoſes between the ſun and the moon, that is, at the full moon; and an eclipſe of the ſun never happens but when the moon comes in a line between the earth and the ſun, that is, at the new moon.

From what we have already ſeen by the inſtrument, it appears that the moon is once every month in conjunction, and once in oppoſition; from hence it would appear, that there ought to be two eclipſes, one of the ſun, the other of the moon,

moon, every month; but this is not the cafe, and for two reafons, firft, becaufe the orbit of the moon is inclined in an angle of about 5 degrees to the plane of the ecliptic; and fecondly, becaufe the nodes of this orbit have a progreffive motion, which caufes them to change their place every lunation. Hence it often happens, that at the times of oppofition or conjunction the moon has fo much latitude, or what is the fame thing, is fo much below or above the plane of the ecliptic, that the light of the fun will in the firft cafe reach the moon, without any obftacle, and in the other the earth; but as the nodes are not fixed, but run fucceffively through all the figns of the ecliptic, the moon is often, both at the times of conjunction and oppofition, in or very near the plane of the ecliptic; in thefe cafes an eclipfe happens, either of the fun or moon, according to her fituation. The whole of this is rendered clear by the lunarium, where the wire projecting from the earth, fhews when the moon is above, below, or even with the earth, at the times of conjunction and oppofition, and thus when there will be, or not, any eclipfes.

The diftance of the moon from the earth varies fenfibly with refpect to the fun; it does not move in a circular, but in an elliptic orbit round us, the earth being at one of the foci of

 this

this curve.* The longer axis of the lunar orbit is not always directed to the ſame point of the heavens, but has a movement of it's own, which is not to be confounded with that of the nodes; for the motion of the laſt is contrary to the order of ſigns, but that of the line of apſides is in the ſame direction, and returns to the ſame point in the heavens in about nine years. This motion is illuſtrated in the lunarium by means of the braſs ellipſis X Y, which is carried round the earth in little leſs than nine years: thus ſhewing the ſituation of the elliptical orbit of the moon, and the place of the apogee in the ecliptic.

Thoſe who wiſh to extend the application of the inſtrument further, may have an apparatus applied to it for explaining the Jovian and Saturnian ſyſtems, illuſtrating the motion of their ſatellites, and of the ring of Saturn. But as this application would extend the price of the inſtrument beyond the reach of moſt purchaſers, I have thought it would be unneceſſary to deſcribe them; the more ſo, as the phænomena they are intended to explain are accurately and clearly deſcribed in ſeveral introductory works of aſtronomy.

OF

* That point of her orbit wherein ſhe is neareſt the earth, is called her PERIGEE; the oppoſite point, in which ſhe is fartheſt off, is called her APOGEE. Theſe two points are called her APSIDES, the apogee is the higher, the perigee the lower apſis.

OF THE PLANETARIUM, TELLURIAN, AND LUNARIUM, REPRESENTED IN PLATE XIX.

It is unneceſſary to enter into a minute deſcription of this inſtrument, as what has been ſaid upon the laſt will apply to this, the difference being but ſmall, and that calculated to render the inſtrument leſs expenſive. It differs from that delineated in plates XVII. and XVIII. in the following particulars:

1. That the parts do not take off, as in the other, for exhibiting the particular phænomena; but the whole is put in motion at the ſame time.

2. That the part, which anſwers the purpoſe of the tellurian, is upon a much ſmaller ſcale than that of plate XVIII.

2. The lunarium only exhibits the monthly motion of the moon round the earth, the inclination of the nodes, and the phaſes.

To leſſen the price ſtill more, ſome of theſe inſtruments are conſtructed with no diurnal motion to the earth.

OF THE ARMILLARY SPHERE, FIG. 1, PLATE XIII.

This inſtrument repreſents a planetarium, as combined, or rather inſerted within an armillary ſphere. The planetarium exhibits the motion of the earth, and all the primary planets,

round the ſun; the parallelifm of the earth's axis, and the moon's motion round the earth, the ſeaſons, &c. may therefore be explained by it; the propriety of placing them in a ſphere, is too obvious to need explanation; the deſcription of the foregoing inſtrument will enable the tutor to uſe this with eaſe to himſelf, and ſatisfaction to his pupil.

Description and Use of the Armillary Sphere, Fig. 1, Plate XIII.

Whoever has ſeen a common armillary ſphere, and underſtands how to uſe it, muſt be ſenſible that the machine here referred to, is of a very different, and much more advantageous conſtruction. And whoever has ſeen the curious glaſs ſphere, invented by Dr. Long, or the figure of it in his aſtronomy, muſt know that the furniture of the terreſtrial globe in this machine, the manner of turning either the earthly globe, or the circles which ſurround it, are all copied from the doctor's glaſs ſphere; and that the only difference is, a parcel of rings inſtead of a glaſs celeſtial globe; and all the additions are, a moon within the ſphere, and a ſemicircle upon the pedeſtal.*

The exterior part of this machine are a compages of braſs rings, which repreſent the principal circles of the heaven, viz. 1. The equinoctial,

* Ferguſon's Lectures, page 194.

equinoctial, which is divided into 360 degrees, (beginning at it's interfection with the ecliptic in Aries) for fhewing the fun's right afcenfion in degrees; and alfo into 24 hours, for fhewing his right afcenfion in time. 2. The ecliptic B B, which is divided into 12 figns, and each fign into 30 degrees, and alfo into the months and days of the year, in fuch a manner, that the degree or point of the ecliptic in which the fun is, on any given day, ftands over that day in the circle of months. 3. The tropic of Cancer C C. 4. The arctic circle E, and the antarctic circle F, each 23 ½ degrees from it's refpective pole at N and S. 5. The equinoctial colure G G, paffing through the north and fouth poles of the heaven at N and S, and through the equinoctial points Aries and Libra, in the ecliptic. 6. The folftitial colure H H paffing through the poles of the heaven, and through the folftitial points Cancer and Capricorn, in the ecliptic. Each quarter of the former of thefe colures, is divided into 90 degrees, from the equinoctial to the poles of the world, for fhewing the declination of the fun, moon, and ftars; and each quarter of the latter, from the ecliptic to it's poles, for fhewing the latitudes of the ftars.

In the north pole of the ecliptic is a nut b, to which is fixed one end of a quadrantal wire, and to the other end a fmall fun Y, which is carried round the ecliptic B B, by turning the nut; and

in

in the ſouth pole of the ecliptic is a pin at d, on which is another quadrantal wire, with a ſmall moon Z upon it, which may be moved round by hand; but there is a particular contrivance for cauſing the moon to move in an orbit which croſſes the ecliptic at an angle of 5 $\frac{1}{3}$ degrees, in two oppoſite points, called the moon's nodes; and alſo for ſhifting theſe points backward in the ecliptic, as the moon's nodes ſhift in the heaven.

Within theſe circular rings is a ſmall terreſtrial globe I, fixed on an axis K K, which extends from the north and ſouth poles of the globe, to thoſe of the celeſtial ſphere at N and S: on this axis is fixed the flat celeſtial meridian L, which may be ſet directly over the meridian of any place on the globe, and then turned round with the globe, ſo as to keep over the ſame meridian upon it: this flat meridian is graduated the ſame way as the braſs meridian of a common globe, and it's uſe is much the ſame. To this globe is fitted the moveable horizon M M, ſo as to turn upon two ſtrong wires proceeding from it's eaſt and weſt points to the globe, and entering the globe at oppoſite points of it's equator, which is a moveable braſs ring let into the globe in a groove all around it's equator: the globe may be turned by hand within this ring, ſo as to place any given meridian upon it, directly under the celeſtial meridian L. The horizon is divided

into

into 360 degrees all around it's outermoſt edge, within which are the points of the compaſs, for ſhewing the amplitude of the ſun and moon, both in degrees and points. The celeſtial meridian L L, paſſes through two notches in the north and ſouth points of the horizon, as in a common globe; but here, if the globe be turned round, the horizon and meridian turn with it. At the ſouth pole of the ſphere is a circle of 24 hours, fixed to the rings, and on the axis is an index which goes round that circle, if the globe be turned round it's axis.

The whole fabric is ſupported on three feet, and may be elevated or depreſſed upon the joint O, to any number of degrees from 0 to 90, by means of the arch P, which is fixed into the ſtrong braſs arm Q, and ſlides in the upright piece R, in which is a ſcrew at r, to fix it at any proper elevation. In the box T are two wheels (as in Dr. Long's ſphere) and two pinions, whoſe axes come out at a and b; either of which may be turned by the milled nuts affixed to them. When the nut b is turned, the terreſtrial globe, with it's horizon and celeſtial meridian, keep at reſt; and the whole ſphere of circles turns round from eaſt, by ſouth, to weſt, carrying the ſun Y, and moon Z, round the ſame way, and cauſing them to riſe above and ſet below the horizon; but when the nut a is turned forward, the ſphere, with the ſun and moon, keep at reſt; and the

earth, with it's horizon and meridian, turn round from weſt, by ſouth, to eaſt; and bring the ſame points of the horizon to the ſun and moon, to which theſe bodies came when the earth kept at reſt, and they were carried round it, ſhewing that they riſe and ſet in the ſame points of the horizon, and at the ſame times in the hour circle, whether the motion be in the earth, or in the heaven. If the earthly globe be turned, the hour index goes round it's hour circle; but if the ſphere be turned, the hour circle goes round below the index.

And ſo, by this conſtruction, the machine is equally fitted, to ſhew either the real motion of the earth, or the apparent motton of the heaven.

To rectify the ſphere for uſe, firſt ſlacken the ſcrew r in the upright ſtem R, and taking hold of the arm Q, move it up or down until the given degree of latitude for any place be at the ſide of the ſtem R, and then the axis of the ſphere will be properly elevated, ſo as to ſtand parallel to the axis of the world, if the machine be ſet north and ſouth by a ſmall compaſs: this done, count the latitude from the north pole, upon the celeſtial meridian L, down towards the north notch of the horizon, and ſet the horizon to that latitude; then turn the nut b, until the ſun Y comes to the given day of the year in the ecliptic, and the ſun will be at it's proper place for that day: find the place of the moon's aſcending node, and

alſo

alſo the place of the moon, by an ephemeris, and ſet them right accordingly. Laſtly, turn the nut b until either the ſun comes to the meridian L, or until the meridian comes to the ſun, (according as you want the ſphere or earth to move) and ſet the hour index to the XII marked noon, and the whole machine will be rectified.

Then turn the nut a, and obſerve when the ſun or moon riſes and ſets in the horizon, and the hour index will ſhew the times thereof for the given day.

Thoſe who underſtand the uſe of the globes, will be at no loſs to work many problems by this ſphere.

ESSAY

ESSAY IV.

AN INTRODUCTION TO PRACTICAL ASTRONOMY.

THERE is no part of mathematical ſcience more truly calculated to intereſt and ſurprize mankind, than the meaſurement of the relative poſitions and diſtances of inacceſſible objects. To determine the diſtance of a ſhip, ſeen on a remote ſpot of the unvaried face of the ocean; to aſcertain the height of the clouds and meteors which float in the inviſible fluid above our heads; or to ſhew with certainty the wonderful dimenſions of the ſun and other bodies in the heavens, are among the numerous problems which to the vulgar appear far beyond the reach of human art, but are nevertheleſs truly reſolved by the incontrovertible principles of the mathematics. Theſe principles, ſimple in themſelves, and eaſy to be underſtood, are applied to the conſtruction

conſtruction of a variety of inſtruments; and the following pages contain an account of their uſe in the quadrant and the equatorial.

The poſition of any object, with regard to a ſpectator, can be conſidered in no more than two ways; namely, as to it's diſtance, or the length of a line ſuppoſed to be drawn from the eye to the object; and as to it's direction, or the ſituation of that line with reſpect to any other lines of direction: or, in other words, whether it lies to the right or left, above or below thoſe lines. The firſt of theſe two modes bears relation to a line abſolutely conſidered, and the ſecond to an angle. It is evident that the diſtance can be directly come at by no other means than by meaſuring it, or ſucceſſively applying ſome known meaſure along the line in queſtion; and therefore, that in many caſes the diſtance cannot be directly found; but the poſition of the line, or the angle it forms, with ſome other aſſumed line, may be readily aſcertained, provided this laſt line do likewiſe terminate in the eye of the ſpectator. Now the whole artifice of meaſuring inacceſſible diſtances, conſiſts in finding their lengths, from the conſideration of angles, obſerved about ſome other line, whoſe length can be ſubmitted to actual menſuration. How this is done I ſhall proceed to ſhew.

Every one knows the form of a common pair of compaſſes. If the legs of this inſtrument were

were mathematical lines, they would form an angle greater or lefs, in proportion to the fpace the points would have paffed through in their opening. Suppofe an arc of a circle to be placed in fuch a manner, as to be paffed over by thefe points, then the angles will be in proportion to the parts of the arc paffed over; and if the whole circle be divided into any number of equal parts, as for example, 360, the number of thefe comprehended between the points of the compaffes, will denote the magnitude of the angle. This is fufficiently clear; but there is another circumftance which beginners are not often fufficiently aware of, and which therefore requires to be well attended to: it is, that the angle will be neither enlarged nor diminifhed by any change in the length of the legs, provided their pofition remains unaltered; becaufe it is the inclination of the legs, and not their diftance from each, or the fpace between them, which conftitutes the angle. So that if a pair of compaffes, with very long legs, were opened to the fame angle as another fmaller pair, the intervals between their refpective points would be very different; but the number of degrees on the circles, fuppofed to be applied to each, would be equal, becaufe the degrees themfelves on the fmaller circle would be exactly proportioned to the fhortnefs of the legs. This property renders the admeafurement of angles very eafy; becaufe the diameter of the meafuring

circle may be varied at pleaſure, as convenience requires. In practice, however, the magnitude of inſtruments is limited on each ſide. If they be made very large, they are difficult to manage, and their weight bearing a high proportion to their ſtrength, renders them liable to change their figure, by bending when their poſition is altered; but on the contrary, if they are very ſmall, the errors of conſtruction and graduation amount to more conſiderable parts of the diviſions on the limbs of the inſtrument.

OF THE QUADRANT, AND IT'S USES.

Every circle being ſuppoſed to be divided into 360 equal parts, or degrees, it is evident that 90 degrees, or one-fourth part of a circle, will be ſufficient to meaſure all angles formed between a fine perpendicular to the horizon, and other lines which are not directed to points below the level. Fig. 1, pl. XX. is a drawing of a very ſimple and uſeful inſtrument of this kind. A B C is a quadrant mounted on an axis and pedeſtal: by means of the axis, it may be immediately placed in any vertical poſition, and the pedeſtal being moveable in the axis of the circle E F, ſerves to place it in the direction of any azimuth, or towards any point of the compaſs. The limb A B is divided into degrees and halves, numbered from A; and upon the radius B C are fixed two ſights, of which B is perforated with a ſmall hole,

and is provided with a dark glaſs, to defend the eye from the ſun's light; and the other ſight C has a larger hole, furniſhed with croſs wires, and alſo a ſmaller, which is of uſe to take the ſun's altitude by the projection of the bright image of that luminary upon the oppoſite ſight. From the center C hangs a plumb line C P. The horizontal circle F E is divided into four quadrants of 90 degrees; and an arm E, connected with the pedeſtal, moves along the limb, and conſequently ſhews the poſition of the place of the quadrant, as will hereafter be more minutely explained. Laſtly, the ſcrews G, H, I, render it very eaſy to ſet the whole inſtrument ſteadily and accurately in it's proper poſition, notwithſtanding any irregularity in the table or ſtand it may be placed upon.

The rationale of this inſtrument is very clear and obvious. It is uſed to meaſure the angular diſtance of any body, or appearance, either from the zenith or point immediately above our heads, or from the horizon or level. The plumb line C P, if continued upwards from C, would be directed to the zenith Z; and the line C L, ſuppoſed to be drawn from the center of the quadrant to an object L, will form an angle L C Z, which is the zenith diſtance, and is equal to the angle B C P, formed between the oppoſite parts of the ſame lines. We ſee, therefore, that the degrees on the arc, comprehended on the limb of the

quadrant,

quadrant, between the plumb line and the extremities next the eye, meaſure the angle of zenith diſtance.

Again, the line C K (forming a right angle with the perpendicular C Z) is level, or horizontal; the angle L C K muſt therefore be the altitude or elevation of L above the horizon; and this laſt angle muſt be equal to the angle meaſured between the plumb line and the end A fartheſt from the eye; becauſe both theſe are equal to the quantity which would be left, after taking the zenith diſtance from a right angle, or the whole quadrant.

The determination of the altitude or zenith diſtance of an object is not ſufficient to aſcertain it's place, becauſe the object may be placed in any direction with reſpect to azimuth, or the points of the compaſs, without increaſe or diminution of it's altitude. Hence it is that an horizontal graduated circle is a neceſſary addition to a quadrant which is not intended to be always uſed in the ſame plane. The bearing or poſition of an object relative to the cardinal points, together with the altitude, is ſufficient to aſcertain the place of any object or phænomenon.

After this ſhort account of the general principles of the quadrant, I ſhall proceed to ſhew ſome of the leading problems reſolved by it.

PROBLEM I.

To adjuſt the quadrant for obſervation.

The quadrant is adjuſted for obſervation when it's plane continues perpendicular to the horizon, in all poſitions of the line of ſight. For this purpoſe, bring the index to 90° on the horizon, and turn one or both of the ſcrews which are fixed oppoſite 60°, till the plumb line lightly touches the plane of the quadrant. Then turn the index to 0°, and make the ſame adjuſtment, by means of the ſcrew at 0°, and the quadrant is ready for obſervation.

Or otherwiſe, ſet the index at 0°, and obſerve the degree marked by the plumb line on the limb: then turn the index to the other 0° which is diametrically oppoſite, and obſerve the degree marked by the plumb line: if it be the ſame as before, there will be no occaſion to alter the ſcrews at 60°; but if otherwiſe, one or both of thoſe ſcrews muſt be turned, till the plumb line interſects the middle degree (or part) between the two. After this operation, the degree marked by the plumb line muſt be obſerved, as before, by ſetting the index at both the 90°, and the adjuſtment of the plumb line to the middle diſtance muſt be made by the ſcrew at O, taking care not to touch the other ſcrews.

The latter method of adjuſtment being more accurate

accurate in practice, may be used after the former.*

PROBLEM II.

To find the distance of an object on the earth, by observations made from two stations on the same level.

OBSERVATIONS.

Chuse two stations, between which the ground is level, and place a visible mark on each. The distance between them ought not to be less than the seventh or eighth part of the estimated distance of the objects; and neither station ought to be considerably nearer the object than the other. Measure the distance between the stations, by means of measuring poles, a chain, or a piece of stretched cork. From one station direct the quadrant to the object, by looking through the hole in one sight, and moving the upright axis about, till the object is seen through the hole in the other, exactly at the intersection of the cross wires. Observe the degrees and parts shewn by the index on the horizontal circle;

* The larger or more expensive instruments have apparatus for setting the axis of motion at right angles to the planes of the horizontal circle and quadrant, the line of sight or collimation parallel to the radius passing through 90°, &c. &c. In the small instruments, described in the text, these adjustments are made by the workman.

circle; then direct the quadrant in the ſame manner to the mark of the other ſtation, and obſerve the degrees and parts ſhewn by the index. The number of degrees and parts intercepted between this and the former poſition of the index, is the angle at the firſt ſtation. The ſame operations repeated at the ſecond ſtation, will give the angle at that ſtation.

SOLUTION.

Take the ſum of the two obſerved angles from 90°, and the remainder will be the angle under which the two ſtation-marks would be ſeen from the object. Then

As the ſine of the angle at the object
Is to the ſine of the angle at one ſtation;
So is the diſtance between the ſtations
To the diſtance of the object from the other ſtation.

Theſe, and all other proportions, may be ſolved by the logarithms, or more ſpeedily by the Gunter's rule.

Solution of the Problem by Protraction.

From a ſcale of equal parts lay down a right line, to repreſent the meaſured baſe.

By means of the protractor, or by the compaſſes and line of chords, draw a line from each extre-

extremity of the baſe, reſpectively forming angles equal to thoſe actually obſerved.

Continue theſe lines till they interſect.

The interval between the point of interſection, and one extremity of the baſe, being taken between the compaſſes, and applied to the line of equal parts, will ſhew the diſtance between the object and the ſtation repreſented by that extremity.

This problem may, in caſes of ſmall diſtance, be conveniently applied to a baſe line meaſured within a room, and the obſervations taken out at the windows.

PROBLEM III.

To find the diſtance of the foot of a tower, by obſervations made on the upper part.

The ſolution of this problem conſiſts in making obſervations on the ſummit, in the ſame manner as in the foregoing problem. The diſtance deduced from the horizontal angles will be that of a point in the horizon, immediately beneath the part on which the obſervations were made.

PROBLEM IV.

To find the height of a ſpire, a mountain, or any other elevation.

 Caſe 1.

Cafe 1. When the diftance of the point immediately beneath the fummit can be meafured.

Obferve the angle of altitude with the quadrant, by viewing the fummit through the fights, and noting the degrees and parts indicated by the interfection of the plumb line. Meafure alfo the horizontal diftance.

Then,

As the co-fine of the obferved angle
Is to the fine of the obferved angle;
So is the meafured diftance
To the height required.

Or by conftruction. Draw a right line equal to the meafured bafe, taken from a fcale of equal parts.

Erect a perpendicular from one extremity, and from the other draw a line inclined towards the perpendicular, and forming an angle with the bafe, equal to the obferved angle.

The interval between the interfection of this laft line, and the perpendicular, and the lower extremity of the perpendicular itfelf, being taken in the compaffes, and applied to the line of equal parts, will fhew the height required.

Cafe 2. When the diftance of the point immediately beneath the fummit cannot be meafured.

Find the diſtance by prob. iii. and the height by caſe 1, of the preſent problem: or otherwiſe,

Meaſure a baſe line directly towards the object, and take the altitude from each end of the baſe.

Then,

Add the obſerved altitudes together; and ſubtract the ſum from 180 degrees.

Then,

As the ſine of this difference
Is to the ſine of the leſs altitude;
So is the baſe line
To the direct diſtance between the ſummit and the nearer end of the baſe line.

And,

As radius
Is to the ſine of the greater altitude;
So is the diſtance laſt found
To the height required.

Or by conſtruction. Set off the baſe line, and from it's extremities draw lines inclined to the baſe in the reſpective angles obſerved, but in ſuch a manner, as that the leſs angle may be formed by the baſe itſelf, and the greateſt by the prolongation of the baſe.

Theſe lines will interſect.

From the point of interſection let fall a perpendicular

pendicular on the prolongation of the baſe, and it will give the height required.

The firſt method of ſolving this caſe is in general the beſt in practice. It is for the moſt part much more eaſy to find a baſe ſufficiently long and level between two ſtations, nearly equidiſtant from the eminence, as the firſt requires, than in a direction towards it, becauſe the ground uſually riſes irregularly towards mountains. And in the latter caſe alſo, if the difference between the two altitudes be not very conſiderable, the reſult will be rendered erroneous by a very ſmall inaccuracy of obſervation.

PROBLEM V.

To plot a field by a baſe line meaſured in the middle.

Set up marks in the corners or angles, and meaſure a line in the field in ſuch a direction, as that it may be as far as poſſible from pointing towards any of the angles. Direct the ſights from one end of the baſe to each of the angles ſucceſſively, and alſo to the other extremity of the baſe, carefully noting the degrees and parts of the horizontal circle, indicated by the index. Repeat the like operations at the other end of the baſe line.

Conſtruction. Draw a faint line upon paper, upon which ſet off, from a ſcale of equal parts, the

the meafured bafe. From it's extremities draw lines, forming the refpective angles obferved. The interfections of thofe lines will fhew the corners, or angles, of the field, and muft be joined by right lines.

This problem being nothing more than a determination of the pofition of the angular points with refpect to the bafe line, by prob. 1, will be more accurate in practice, the more nearly the conditions there expreffed are adhered to. If a bafe line cannot be had in view of all the angles, and in a convenient pofition, two or more bafe lines may be meafured, and connected together by the obfervation of the requifite angles; or the three fides of a triangle may be meafured in the field, according to the difcretion of the ingenious learner, and the bearings of the corners of the field taken from fuch extremities of any of thefe meafured lines, as are beft adapted to the purpofe.*

As

* It may be proper to obferve, for the ufe of fuch as are unacquainted with furveying of land, that the Englifh acre is 4840 fquare yards, and that land is moft conveniently meafured by the Gunter's chain of 22 yards in length, divided into 100 links; becaufe the fquare chain, or 22 multiplied by 22, equal to 484, is exactly the tenth part of an acre. If the plot of a field meafured in chains and links, be therefore made upon paper, and divided into a number of triangles, by drawing right lines within it, the bafe and perpendicular of each triangle may be meafured from the

As this method is very far from being laborious, the practitioner will do well to meaſure the field twice, from a different baſe each time.

PROBLEM VI.

To plot a field, by meaſuring the ſides and angles.

Set up marks at each of the angles, and at every one of theſe marks direct the quadrant to the two adjacent marks on each ſide. The number of degrees and parts between the two poſitions of the index on the horizontal circle, will ſhew the angle at the ſtation where the obſervation is made. Meaſure the diſtance to the next ſtation, and obſerve the angle there in the ſame manner. And thus proceed completely round the field.

Conſtruction. From the ſcale of equal parts draw a line equal to the firſt meaſured ſide, and from it's extremities draw two lines, forming angles equal to thoſe actually obſerved.

Make

the ſcale of equal parts, and half their product will be the area of the triangle in ſquare chains; the ſum of all the areas of the triangles will be the area of the field, which divided by 10, will ſhew the number of acres; the remaining decimal fraction multiplied by 4, gives the roods; and the decimal part of this laſt product multiplied by 40, gives the perches.

Make these last lines equal to the sides they represent, and from their extremities draw two other lines at angles respectively found by observation.

Proceed thus, till the whole field is plotted.

When all the angles of a field are thus measured, their sum, if the operation has been truly made, will be equal to twice as many right angles, deducting four, as there are angles in all, provided they be all inward angles. But if any of them be outward angles, their respective supplements to 360° must be taken in making up the sum instead of the angles themselves. When the sum proves either greater or less than just the figure, it will not answer on paper; and as observations made with small instruments cannot be expected to be free from perceptible errors, it will be expedient to correct the angles by adding or subtracting such defect or excess, to or from all the angles, in proportion to their magnitude, or more readily in equal proportions among them.

This way of measuring is much used in America, by the measuring wheel and mariner's compass, and is applicable to extensive woody or mountainous tracts of land, where great accuracy is not required. It may also be used in conjunction with other methods, for delineating a sea-coast, &c.

PROBLEM

PROBLEM VII.

To find the altitude and height of fire balls, and other meteors, in the atmoſphere.

Though the extreme velocity and tranſient nature of fiery meteors in the atmoſphere in a great meaſure prevents the making of ſuch obſervations as might tend to aſcertain their diſtance, yet they form a ſubject of inquiry ſo curious and intereſting, as renders ſuch as can be made of great value. An obſerver, who perceives an appearance of this kind, ought carefully to note the buildings, trees, ſtars, &c. near which it paſſes; and as ſoon afterwards as convenient take their altitude and bearings. If two ſuch obſervations be taken by perſons at different places, ſufficiently diſtant from each other, the diſtance on the earth may be conſidered as the baſe, and from this and the two obſerved angles the height of the meteor may be found by problem ii.

By obſervations of this kind it has been found, that the larger fire balls are elevated about 60 miles above the earth's ſurface, and that ſome of them are near five miles in diameter.

PROBLEM VIII.

To find the height of a cloud, by obſervation of a flaſh of lightning.

If the altitude of that part of a cloud, from which

which a flash of lightning has issued, be immediately taken with the quadrant, and the number of seconds of time elapsed between the instant of the flash, and the first arrival of the thunder be reckoned, these data will be sufficient to determine the height of the thunder cloud. For sound is admitted to pass through 1142 feet in a second; but light has such an extreme velocity, that it passes through thirty-five thousand miles in a second, and may therefore be reckoned instantaneous in all observations upon the earth. Hence it follows, that the number of seconds observed, multiplied by 1142, will give the distance of the cloud in feet; and

As radius
Is to the sine of the observed angle;
So is the distance of the cloud
To it's height.

Or by construction. From a point in any right line, draw another right line, forming the observed angle. Set off on this left line, from the angular point, the distance of the cloud, taken from a scale of equal parts. From the extreme of the last-mentioned line let fall a perpendicular on the other line; and this perpendicular will be the height required.

If the flash of lightning strike directly down, the height of the cloud will also be the length of the flash. But this is not often the case.

PROBLEM

PROBLEM IX.

To determine the height of a cloud, by obſervations on it's altitude and velocity.

When the ſky abounds with detached clouds, moving with conſiderable velocity, it is eaſy to determine the degree of ſwiftneſs, by obſerving the progreſs of their ſhadows which paſs along the ground. For this purpoſe, nothing more is neceſſary, than to note the inſtants of time when one of theſe ſhadows paſſes over two objects, ſuch as hedges, trees, &c. lying in it's direction; and to meaſure the interval paſſed over, during the intermediate time. When this velocity is thus found, place the plane of the quadrant in the direction of the wind, and ſetting the ſights to a conſiderable altitude, to be written down, take notice of ſome remarkable edge of a cloud, which paſſes acroſs the wire in the aperture of the fartheſt ſight, giving notice at the ſame inſtant to an aſſiſtant to note the time. Then move the quadrant on it's axis twenty or thirty degrees, and give the like notice to the aſſiſtant when the ſame part of the cloud paſſes the wire; write down this laſt altitude. The perpendicular height of the cloud will be found by the following proportions.

As the number of ſeconds obſerved when the ſhadow of the former cloud was ſeen on the ground
Is to the number of ſeconds elapſed between the two obſervations with the quadrant;
So is the diſtance meaſured on the ground
To the diſtance paſſed through by the cloud (whoſe altitude was taken) during the time of obſervation.

Then,
As the ſine of the difference between the ſum of the two altitudes and 180°
Is to the ſine of the leſs altitude;
So is the diſtance paſſed over by the cloud,
To it's diſtance from the obſerver, when the greater altitude was taken.

And laſtly,
As radius
Is to the ſine of the greater altitude;
So is the diſtance laſt found
To the perpendicular height of the cloud.

PROBLEM X.

To find the altitude of the ſun, or any other celeſtial body.

This conſiſts in the ſimple application of the quadrant to a celeſtial body, in the ſame manner as has already been ſhewn with regard to terreſtrial objects. The quadrant being rectified or adjuſted by problem 1, as it muſt be in all caſes

previous to it's uſe, the celeſtial body muſt be viewed through the ſights, and the plumb-line will ſhew it's altitude on the graduated limb of the inſtrument. If the obſervation be made on the ſun, the dark glaſs muſt be uſed to defend the eye, or the luminous ſpot formed by the ſmaller hole of that ſight which carries the croſs wires, muſt be made to fall on the mark on the other ſight which lies immediately beneath the eye-hole.

PROBLEM XI.

To find the latitude of the place of obſervation.

When the ſun, or a ſtar, is nearly on the meridian, or a few minutes before twelve at noon, take it's altitude, and repeat this operation at ſhort intervals of time, till it is found not to increaſe, but diminiſh. This laſt or greateſt altitude is the meridian altitude.

In places where the ſun does not ſet, the leaſt altitude is the meridian altitude beneath the pole.

The rule for finding the latitude by the meridian altitude of an object not beneath the pole, is as follows:

If the co-altitude and declination* be of the ſame name, (that is, either both north, or both ſouth) their difference will be the latitude; if of different

* The declination of the ſun, and moſt other moveable celeſtial bodies, is to be found in the ephemerides.

different names, their ſum will be the latitude. And the latitude will always be of the ſame name with the declination, excepting when the declination has been ſubtracted from the co-latitude.

But when the altitude is beneath the pole, the following is the rule:

Add the altitude and the co-declination together, and the ſum will be the latitude of the ſame name with the declination.

PROBLEM XII.

To find the time by equal altitudes of the ſun.

Obſerve the ſun's altitude in the morning, and alſo the time by a clock or watch. Leave the quadrant in the ſame ſituation, taking care that it's poſition be not altered by any accident; and in the afternoon direct it to the ſun, by moving the index of the horizontal circle only. Add the time when the ſun's altitude correſponds with that to which the quadrant was ſet in the morning. The middle inſtant between the two times of obſervation, is the time of apparent noon. Correct this, by adding or ſubtracting the equation of time, and it will ſhew the time of true noon. If it be preciſely XII, the clock is right; but if it differ, the clock is faſter or ſlower, by the quantity of the difference greater or leſs than XII.

PROBLEM XIII.

To draw a meridian line, or to find the cardinal points of the compaſs, by equal altitudes of the ſun, or a ſtar.

If equal altitudes of the ſun be taken as directed in the foregoing problem, and the place of the index on the horizon circle be carefully noted at each time of obſervation, the middle degree or part between each, will be the place where the index will ſtand, when the ſights of the quadrant are directed to the ſouth, or north, according as the ſun is to the ſouthward or northward of the place of obſervation at noon. Set the index to this middle point, and direct the ſights of the quadrant to ſome remote and fixed object on the earth. This object will be a ſouth meridian mark, and will ſerve to ſet the quadrant at any future time. Then take up the inſtrument, and after ſetting the index to 0, place again on the table, or ſupport, and move the whole inſtrument, not by any of it's parts, but entirely about upon the table, till the ſights are truly directed to the meridian mark. Adjuſt the horizontal circle by prob. 1, and the index will then ſerve to ſhew the true bearing of any object; becauſe the diameter joining the two zeros, or 00's, anſwers to the meridian line.

If the table, or ſupport, be immoveable, it will be proper to make three marks, or indenta-

tions,

tions, to receive the points of the ſcrews; by which means the horizontal circle may be inſtantly, at any time, ſet in it's proper poſition, with reſpect to the cardinal points of the horizon.

Obſervations of equal altitude are, generally ſpeaking, better, the greater the interval is between them, not exceeding 12 hours; and theſe obſervations on the ſun require ſome correction, on account of the change of it's declination during the time of obſervation. The young aſtronomer with ſmall inſtruments may, however, neglect this; and indeed it is of little conſequence about the ſolſtices, when the ſun's declination changes very ſlowly.

It often happens that there is not any window in a houſe, from which the ſun can be ſeen morning and evening. In this caſe, the meridian may be determined by obſervations of equal altitude of the pole ſtar, or any other near the pole.

PROBLEM XIV.

To find the time by the ſun's tranſit over the meridian.

Adjuſt the quadrant to the cardinal points by the laſt problem, a ſhort time before noon. Set the index to 0, and elevate the quadrant, ſo that the ſhadow of the ſight with the croſs wires may fall upon the other. As the inſtant of apparent

noon approaches, the bright ſpot formed by the ſun's light through the lower hole in the former ſight, will be ſeen approaching the mark on the latter. If the obſerver chuſes to look at the ſun, he muſt now put up the dark glaſs, and apply to the obſervations. The inſtants when the firſt limb or edge of the ſun appears to touch the perpendicular wire, and alſo when the latter limb appears to leave it, muſt be noted by the clock or watch. The middle time is the apparent noon. Or if he chuſes to obſerve by the bright ſpot only, the inſtant when the ſpot is ſeen upon the mark is the apparent noon. And this corrected by the equation of time, as directed in prob. xii. will ſhew how much the clock is faſt or ſlow.

PROBLEM XV.

To find the time by an obſervation of the ſun's altitude and azimuth.

Adjuſt the inſtrument to the cardinal points, and obſerve the ſun's altitude. Take notice likewiſe of the angle of azimuth from the meridian, as ſhewn by the index.

Then,

As the ſine complement of the ſun's declination
Is to the ſine complement of the altitude;
So is the ſine of the azimuth
To the ſine of the ſun's horary angle.

Which

Which laſt being reduced into time, by allowing fifteen degrees to one hour, and in proportion for the other parts, gives the apparent time, if afternoon; but if before noon, it muſt be deducted from 12 hours, to give the time. This apparent time muſt be corrected by the equation, as in problem xii.

OF THE EQUATORIAL, OR UNIVERSAL SUN-DIAL, AND IT'S USES.

The plumb-line, or direction in which gravity acts, being the only line we can at all times have immediate recourſe to, for determining the poſitions of objects, is the chief particular to which the circles in the inſtrument laſt deſcribed are adapted; and accordingly their planes are placed the one parallel, and the other perpendicular to that line. But as there are few places on the earth whoſe vertical or horizontal circles correſpond with thoſe in which the celeſtial motions are performed, it was found neceſſary, at a very early period, to conſtruct inſtruments adapted not only to the meaſurement of altitudes and azimuths, but alſo to follow the heavenly bodies in their reſpective paths, and determine their right aſcenſions and declinations, more immediately than can be done by the quadrant and horizontal circle. The equatorial is the moſt approved modern inſtrument for this purpoſe.

It consists of the following parts:

An horizontal circle E F, plate XX, fig. 2, divided, like that of the former instrument, into four quadrants, of 90° each. But instead of a moveable index there is a fixed nonius plate at N, and the circle itself may be turned on it's axis.

In the center of the horizontal circle is fixed a strong upright pillar, which supports the center of a vertical semicircle A B, divided into two quadrants of 90° each. This is called the semicircle of altitude, and supplies the place of the quadrant in the former instrument; but it is more extensively useful, because one quadrant serves to measure altitudes, and the other depressions. It has no plumb-line, but a nonius plate at K.

At right angles to the plane of this semicircle, the equatorial circle M N is firmly fixed. It represents the equator, and is divided into twice twelve hours, every hour being divided into twelve parts, of five minutes each.

Upon the equatorial circle moves another circle, with a chamfered edge, carrying a nonius, by which the divisions on the equatorial may be read off to single minutes; and at right angles to this moveable circle, is fixed the semicircle of declination D, divided into two quadrants of 90° each.

The piece which carries the sights O P is fixed

fixed to an index moveable on the ſemicircle of declination, and carrying a nonius at Q. The ſight O, to which the eye is to be applied, has two ſmall holes, and a dark glaſs for covering either occaſionally; and the ſight P has two pieces ſcrewed on, the lower having a ſmall hole to admit the ſolar ray, and the upper carries two croſs wires.

Laſtly, there are two ſpirit levels fixed on the horizontal circle at right angles to each other.

The following are among the many problems which may be ſolved with peculiar facility, by means of this uſeful inſtrument.

PROBLEM XVI.

To adjuſt the equatorial for obſervation.

Set the inſtrument on a firm ſupport. Firſt, to adjuſt the levels, and the horizontal or azimuth circle. Turn the horizontal circle, till the beginning O of the diviſions coincides with the middle ſtroke of the nonius, or near it. In this ſituation, one of the levels will be found to lie either in a right line joining the two feet ſcrews which are neareſt the nonius, or elſe parallel to ſuch a right line. By means of the two laſt-mentioned ſcrews, cauſe the bubble in the level to become ſtationary in the middle of the glaſs; then turn the horizontal circle half round, by bringing the other O to the nonius; and if the bubble remains in the middle, as before, the level

level is well adjusted; if it does not, correct the position of the level, by turning one or both of the screws which pass through it's ends, (by means of a turn-screw) till the bubble has moved half the distance it ought to come to reach the middle; and cause it to move the other half, by turning the foot screws already mentioned. Return the horizontal circle to it's first position, and if the adjustments have been well made, the bubble will remain in the middle; if otherwise, the process of altering the level and the foot-screws, with the reversing, must be repeated till it bears this proof of it's accuracy. Then turn the horizontal circle till 90° stands opposite to the nonius; and by the foot-screw, immediately opposite the other 90°, (without touching the others) cause the bubble of the same level to stand in the middle of the glass. Lastly, by it's own proper screws set the other level (not yet attended to) so that it's bubble may occupy the middle of it's glass.

Secondly, to adjust the line of sight. Set the nonius on the declination semicircle at O; the nonius on the horary circle at VI; and the nonius on the semicircle of altitude at 90°. Look through the sights towards some part of the horizon, where there is a diversity of remote objects. Level the horizontal circle, and then observe what object appears on the center of the cross wires. Reverse the semicircle of altitude, so that

that the other 90° may apply to the nonius; taking care, at the ſame time, that the other three noniuſes continue at the ſame parts of their reſpective graduations as before. If the remote object continues to be ſeen on the center of the croſs wires, the line of ſight is truly adjuſted; but if not, unſcrew the two ſcrews which carry the frame of the croſs wires, and move the frame till the interſection appears to lie on a new object, half way between the object firſt obſerved, and that to which the wires are applied in the laſt poſition. Return the ſemicircle of altitude to it's original poſition: if the interſection of the wires be then found to be on the object to which they were laſt directed, the line of ſight is truly adjuſted; but if not, the frame muſt be again altered as before: and the ſame general operation muſt be repeated, till the croſs wires in both poſitions apply to the ſame object.

Beſides this adjuſtment of the center of interſection, it is neceſſary that one of the wires ſhould be in the plane of the declination ſemicircle, and the other at right angles to that plane. As the wires are fixed at right angles to each other, the adjuſtment of one of them will be ſufficient. For this purpoſe, obſerve any ſmall object on one of the wires: if it be the vertical wire, move the index of the ſemicircle of declination; or if the other, move the laſt-mentioned ſemicircle on the axis of the equato-

rial

rial circle. In either caſe the object will coincide with the wire during it's motion, if the poſition be right; if not, alter that poſition, taking care not to diſplace the center from it's adjuſtment.

To adjuſt the piece which carries the hole for forming the ſolar ſpot, direct the ſights to the ſun, ſo that the center of the luminous circle formed by the aperture which carries the croſs wires, may fall preciſely on the upper ſight hole. Then move the frame, with the ſmall perforation, till the ſolar ſpot falls exactly on the lower ſight-hole.

Thirdly, to find the correction to be applied to obſervations by the ſemicircle of altitude. Set the nonius on the declination ſemicircle to O; and the nonius on the horary circle to XII. Direct the ſights to any fixed and diſtinct object, by moving the horizontal circle and ſemicircle of altitude, and nothing elſe. Note the degree and minute of altitude or depreſſion. Reverſe the declination ſemicircle, by directing the nonius on the horary circle to the oppoſite XII. Direct the ſights again to the ſame object, by means of the horizontal circle and ſemicircle of altitude, as before. If it's altitude, or depreſſion, be the ſame as was obſerved in the other poſition, no correction will be required; but if otherwiſe, half the difference of the two angles is the correction to be added to all obſervations or

or rectifications made with that quadrant, or half of the semicircle, which shew the least angle; or to be subtracted from all observations or rectifications made with the other quadrant, or half.

When the levels and cross wires are once truly set, they will preserve their adjustment a long time, if not deranged by violence: and the correction to be applied to the semicircle of altitude, is a constant quantity.

PROBLEM XVII.

To measure angles, either of azimuth, altitude, or depression.

Set the middle mark of the nonius on the declination at O, and fix it by means of the milled screw behind. Set the horary circle at XII on the equator, and the instrument (previously adjusted) is ready for observation. Then if the sights be directed successively to any two objects, the degrees and minutes contained between the two positions of the nonius, on the limb of the horizontal circle, will shew the horizontal angle in the same manner as has been described at prob. ii. of the quadrant. And likewise, if the sights be directed to any object, by moving the horizontal circle and semicircle of altitude, the degree and minute marked by the nonius on the last-mentioned semicircle will be the angle of altitude, if on the quadrant or part nearest the

the eye, or of depreſſion, if on the remoter quadrant.

Remark. It is proper in this place to deſcribe the nature and uſe of the admirable contrivance commonly called a nonius. It depends on the ſimple circumſtance, that if any line be divided into equal parts, the length of each part will be greater, the fewer the diviſions; and contrariwiſe, it will be leſs in proportion as thoſe diviſions are more numerous. Thus it may be obſerved, that the diſtance between the two extreme ſtrokes on the nonius, in the equatorial before us, is exactly equal to 11 degrees on the limb, but that it is divided into 12 equal parts. Each of theſe laſt parts will therefore be ſhorter than the degree in the proportion of 11 to 12; that is to ſay, it will be one-twelfth part, or 5 minutes ſhorter. Conſequently, if the middle ſtroke be ſet preciſely oppoſite to any degree, the relative poſitions of the nonius and the limb muſt be altered 5 minutes of a degree, before either of the two adjacent ſtrokes next the middle, on the nonius, can be brought to coincide with the neareſt ſtroke of a degree; and ſo likewiſe, the ſecond ſtrokes on the nonius will require a change of 10 minutes; the third, of fifteen, and ſo forth to thirty, when the middle line of the nonius will be ſeen to be equi-diſtant between two of the ſtrokes on the limb; after which, the lines on the oppoſite ſide of the

4 nonius

nonius will coincide in fucceffion with the ftrokes on the limb.

It is clear from this, what whenever the middle ftroke of the nonius does not ftand precifely oppofite to any degree, the odd minutes, or diftance between it and the degree immediately preceding, may be known by the number of the ftroke on the nonius, which coincides with any of the ftrokes on the limb. It muft be obferved, however, that as the degrees in feveral quadrants are reckoned in oppofite directions, fo likewife the nonius has two fets of numbers; for the ufe of which, it need only be remembered, that they always begin from the middle, and go to 30 minutes, and thence from the oppofite 30 minutes in the fame direction to the middle; and that they muft always be reckoned in the oppofite direction to the degrees on the limb.*

PROBLEM XVIII.

To find the diftance of an object on the earth, by obfervations made at two ftations.

This may be done by meafuring a bafe line and the horizontal angles, and proceeding as directed at

* In this inftrument they muft be read in the oppofite direction; but when the nonius plate has it's divifions fewer than the number of parts on the limb to which it is equal, they coincide fucceffively in the fame direction as that of the motion of the index.

at problem ii. But as the equatorial meaſures angles of depreſſion, as well as elevation, the ſtations may not only be on the ſame level, but may be vertically the one above the other. For example, if the altitude of any object be taken from a lower window of any building, and it's depreſſiion from a window immediately above, and the diſtance of the two ſtations of the inſtrument be accurately meaſured,

Then,

As the ſine of the ſum of the angles of altitude and depreſſion, (or of the difference, if both be altitude, or both depreſſion)
Is to the ſine of the angle at the upper ſtation;
So is the diſtance between the ſtations
To the diſtance of the object from the lower ſtation.

PROBLEM XIX.

To meaſure heights and diſtances.

As the ſemicircle of altitude anſwers every purpoſe of the quadrant, in the inſtrument before deſcribed, and the horizontal circle is common to both, it will be eaſy for the intelligent learner to perform the problems iii. iv. vii. viii. and ix. by the equatorial, from the inſtructions given under each reſpectively.

PROBLEM XX.

To plot a piece of land.

The problems v. and vi. with all others which

which are ſolved by the menſuration of horizontal angles, may likewiſe be performed with facility by the equatorial.

PROBLEMS XXI. XXII. XXIII. and XXIV.

Under this title it may be obſerved, that the problems xi. xii. xiii. xiv. and xv. for finding the latitude, the time by equal altitudes, the poſition of the cardinal points, and the time by the ſun's tranſit over the meridian, or by it's altitude and azimuth, may be performed with equal eaſe, and greater accuracy, by the horizontal circle and ſemicircle of altitude, in the inſtrument before us, as by the quadrant treated of under thoſe problems.

I ſhall now proceed to ſome of the problems, to which the equatorial is more peculiarly adapted.

PROBLEM XXV.

To find the latitude of a place, the ſun's declination being known.

Place the adjuſted equatorial, a ſhort time before noon, in ſuch a poſition, that the planes of the ſemicircles of altitude and declination may be as near the meridian as eſtimation will allow; and let the ſight which carries the croſs wires be turned to the point of the compaſs, (either north or ſouth) to which the ſun will come at noon.

Set the index on the declination ſemicircle to the degree and minute of the ſun's declination, either to the north or ſouth ſide of O, as the caſe may be. Then by means of the horizontal circle and ſemicircle of altitude, without touching the declination ſemicircle, cauſe the ſolar ſpot to fall on the mark in the oppoſite ſight, (or obſerve the ſun itſelf by the croſs wires). Keep the ſights in this manner directed to the ſun, till his altitude begins to diminiſh. The degree and minute on the ſemicircle of altitude is the co-latitude, and the latitude will be north, if that degree and minute be upon the northernmoſt quadrant; but if otherwiſe, ſouth.

PROBLEM XXVI.

To find the meridian line, and the time, from one obſervation of the ſun, when it's declination and the latitude of the place are known.

This problem requires that both the azimuth and altitude of the ſun ſhould alter quickly; and this is, generally ſpeaking, the caſe, more eminently, the farther that luminary is from the meridian. Therefore,

At the diſtance of ſeveral hours, either before or after noon, adjuſt the horizontal circle; ſet the ſemicircle of altitude, ſo that it's nonius may ſtand at the co-latitude; lay the plane of the laſt-mentioned ſemicircle in the meridian, by eſtimation, it's O being directed towards the depreſſed

depreſſed pole; place the nonius of the declination ſemicircle to the declination, whether north or ſouth. Then direct the line of ſight towards the ſun, partly by moving the declination ſemicircle on the axis of the equatorial circle, and partly by moving the horizontal circle on it's own axis. There is but one poſition of theſe which will admit of the ſolar ſpot falling directly on the mark on the oppoſite ſight. When this poſition is obtained, the nonius on the equatorial, or horary circle, ſhews the apparent time, and the circle of altitude is in the plane of the meridian.

PROBLEM XXVII.

To find the time, when the latitude, the ſun's declination, and the meridian are known.

The meridian being found by equal altitudes of the ſun, or a ſtar, which is the beſt method, and ſettled by a meridian mark, or by indentation, to ſet the ſcrews in, (prob. xiii.) place the equatorial accordingly, and adjuſt it by the levels. Set the ſemicircle of altitude to the latitude of the place, and the index of the line of ſight, to the declination of the ſun. Turn this laſt ſemicircle, till the ſights are accurately directed to the ſun. The nonius will ſhew the time on the horary circle.

This problem is more accurate than the foregoing, and may be applied at all times when the ſun is viſible.

PROBLEM XXVIII.

To find the meridian line, when the time, the ſun's declination, and the latitude of the place are known.

Adjuſt the inſtrument. Set the ſemicircle of altitude to the latitude, and the nonius of the declination ſemicircle to the declination; and ſet the nonius of the horary circle to the apparent time. Turn the horizontal circle till the ſights are directed to the ſun. The ſemicircle of altitude is then in the plane of the meridian.

This problem gives the poſition of the meridian more accurately than problem xxvi. It is much more ready where the time can be had, than the method of equal altitudes, and it is near enough to the truth of ſmall inſtruments. The nearer the obſervation is made to the time of noon, the better, becauſe the ſun then changes it's azimuth the quickeſt.

PROBLEM XXIX.

To find the declination of the ſun, or any celeſtial object, when the latitude of the place, and poſition of the meridian, are known.

Rectify the inſtrument for the latitude, as in the foregoing problem; and place the ſemicircle of altitude in the meridian. Then direct the ſights

ſights to the object, partly by moving the declination ſemicircle on the axis of the equatorial circle, and partly by moving the nonius of the ſemicircle laſt-mentioned. This nonius will then ſhew the declination.

PROBLEM XXX.

To find the right aſcenſion of any celeſtial object, when the time, the latitude, and the poſition of the meridian, are known.

Perform the operations directed in prob. xxix. Place the ſight ſo that the vertical wire may be a little to the weſtward of the object; and obſerve by a clock, or watch, the apparent or ſolar time when it croſſes the wire. The ſhorteſt interval between the time of obſervation and the time marked on the equatorial circle, by the nonius, is the difference between the times of each luminary coming to the window.

If the ſtars precede the ſun, this difference muſt be ſubtracted from, or if otherwiſe, added to the ſun's right aſcenſion; and the difference, or ſum, will be the ſtar's right aſcenſion, provided it do not exceed 24 hours; if it do, the exceſs is the right aſcenſion.

If the ſun's right aſcenſion ſhould be too ſmall to admit of taking the difference from it, it muſt itſelf be taken from the difference; and the ſupplement of the remainder to 24 hours, will be the ſtar's right aſcenſion.

PROBLEM XXXI.

To direct the line of fight to any ftar or planet.

Adjuft the inftrument to the latitude and meridian, and fet the nonius on the declination circle to the declination of the ftar. Then take the difference between the right afcenfion of the fun and ftar; and if the right afcenfion of the ftar be greater than that of the fun, fubtract the difference; if not, add it to the time of obfervation. The remainder, or fum, will be the hour and minute to which the nonius on the horary circle is to be fet; which being done, the fights will point to the ftar or planet fought.

If the time be too fmall to admit of having the difference taken from it, borrow 24 hours, and reckon the remainder from XII at noon.

When the ftar or planet has, by the diurnal motion of the earth, been carried out of the field of view, in which the crofs wires are placed, it may be readily overtaken, by moving the declination femicircle on the equatorial circle.

There are many other pleafant and ufeful problems, both terreftrial and aftronomical, which may be folved by thefe inftruments; but they cannot here be enlarged on, confiftently with the intended limits of the prefent work. The intelligent ftudent will difcover fome of them himfelf, and for the reft he may confult Atwood's Analyfis of a Courfe of Lectures, De

La

La Lande's Aſtronomie, and other approved authors. It will be ſeen, likewiſe, that I have not entered into the minute conſiderations of refractions, the variation of declinations, and other elements for parts of days, &c. neither have I deſcribed any of the ingenious artifices, by which the errors of inſtruments are either corrected or allowed for. In this, alſo, I think the judicious teacher will join me in opinion, that though they are deſervedly eſteemed of the higheſt importance in the accurate operations of modern aſtronomy, yet it would not have been adviſeable to have diverted the attention of the learner, before his curioſity was excited by a diſplay of the leading particulars, even on the ſuppoſition that my plan could have allowed room for entering into ſuch a detail.

The learner need not, however, be too diffident in attempting to diſcover them by his own reflections, after he has acquired a perfect knowledge of the contents of the foregoing pages. There is no doubt but he will then ſee with that pleaſure which attends ſucceſsful inveſtigation, the excellence of the equatorial, and the numerous methods by which it's parts may be made to co-operate, in producing much more accurate reſults than it's ſize may ſeem to promiſe. In the mean time I ſhall conclude this article with a deſcription of an improved equatorial, in which every endeavour has been uſed to unite

ſimplicity of conſtruction with delicacy and preciſion of workmanſhip.

Description of the Improved Equatorial.

The leading requiſites in good aſtronomical inſtruments, are, 1. the parts muſt be firmly connected, ſo that they may always preſerve the ſame figure; 2. the arcs muſt be truly centered, and accurately graduated; and 3. the extremity of the line of ſight muſt in all ſimple motions deſcribe a true circle. The two former either are or ought to be found in all inſtruments, whatever may be their form; but the latter property requires a particular conſtruction. It is obvious, that when the line of ſight, or teleſcope, is moved on the ſurface of one of the circles of an inſtrument, it's motion will be affected by every irregularity or deviation of that ſurface from a true plane; but on the contrary, if the motions be performed about axes well fitted, the extremity of the line of ſight will in all ſituations remain directed to ſome point in the circle, in which it may be placed. The difficulty of obtaining and preſerving the true ſurface in the former caſe, has induced all aſtronomers to give the preference to axes of motion, in ſuch inſtruments as are intended to be uſed in obſerving tranſits of the celeſtial bodies, acroſs the plane of the circle in which the line of ſight is moved; and as a great part of the obſervations made with

with the equatorial, are of the nature of thoſe tranſits, it is a very deſirable quality that all it's movements ſhould be made upon axes, inſtead of their being governed by the plane of the circles it is compoſed of.

In the preſent inſtrument (plate XXI.) this circumſtance is particularly attended to. E F is the horizontal circle firmly connected to another circular piece by ſix vertical pillars. The diſtance between theſe two circles affords a convenient ſituation for a ſtrong upright axis on which the whole of the upper part of the inſtrument may be horizontally turned. The circular piece, which is ſcrewed upon the head of the vertical axis, carries a ſpirit level. It alſo has an adjuſting ſcrew on one of it's edges, and a nonius plate on the other, which ſhews minutes. This piece ſupports the two uprights, upon which the axis of the ſemicircle of altitude A B turns. At right angles to the ſemicircle of altitude is fixed the equatorial or horary circle, from the center of which laſt proceeds a ſtrong axis, that carries the apparatus for ſupporting the teleſcope. The horary motion of the teleſcope is performed by an adjuſting ſcrew, connected with an index that carries a nonius, for dividing the hours into portions of ten ſeconds each. The teleſcope has a ſtrong but light axis, whoſe circular ends turn in moveable ſockets of hard metal, one of which is capable of a vertical, and

and the other of an horizontal adjuſtment. One end of the axis is perforated, and has a ſmall convex lens ſet in the opening, through which, by the help of a reflector within, the croſs wires may be illuminated for making obſervations on the ſtars at night. The ſemicircle of declination D is affixed to the teleſcope, and paſſes very near a nonius Q, which ſhews minutes on the limb. I ſhall now proceed to deſcribe the method of adjuſtment and obſervation, which will render a more minute enumeration of the parts unneceſſary, and will at the ſame time ſhew their uſe much better than can be done by mere deſcription.

An attentive view of the inſtrument, or drawing, compared with what has been ſaid before, at problem xvi. will ſhew that it's perfect adjuſtment conſiſts in the following particulars. 1. The horizontal circle E F muſt be truly level. 2. The plane of the ſemicircle of altitude A B muſt be truly perpendicular to the horizon, or it's axis muſt be level. 3. The horary circle M N muſt be parallel to the horizontal circle E F, when the nonius of the ſemicircle of altitude marks o degrees; or at leaſt the error of the poſition of the nonius muſt be found. 4. The axis of the horary circle, or the polar axis, muſt be at right angles to the plane of that circle. 5. The line of ſight, or optical axis of the teleſcope, muſt be at right angles to it's axis of motion.

motion. 6. The crofs axis of the telefcope muft be parallel to the plane of the horary circle; and (7.) parallel to that of the femicircle of altitude, when the nonius marks the hour of VI. Laftly, the line of fight muft be parallel to the horary circle, when the nonius of the femicircle of declination marks o degrees.

The manner of making thefe adjuftments may be as follows. 1. Level the horizontal circle as defcribed in problem xvi. 2. The plane of the femicircle of altitude is adjufted in the original conftruction of the inftrument: 3. Set the horary index at XII, and direct the telefcope to a remote object; fet the index to the oppofite XII, and turn the horizontal moveable circle half round. If the telefcope then points to the fame object, the horary circle is parallel to the horizon; if not, alter the pofition of the femicircle of altitude, till the telefcope continues to point to one fingle object in both pofitions of the horary index. When this adjuftment is made, take notice of the fituation of the nonius of the femicircle of altitude; if it cuts at o degrees, it is rightly placed; if not, note the difference, to be applied as a correction of all obfervations made with that femicircle. 4. The axis of the horary circle is truly placed in the conftruction. 5. Caufe the vertical crofs wire of the telefcope to interfect a remote object, the adjufting fcrews of the horizontal and horary circles being previoufly

viously made faſt; then reverſe the poſition of the axis, ſo that the ſemicircle of declination may be upwards inſtead of downwards. By the motion on the axis it will be ſeen whether the ſame croſs wire interſects the object ſeen in the former poſition; if it do, the line of ſight is at right angles to the axis of motion; but if not, alter the poſition of the croſs wires, by means of the two ſmall ſcrews near the eye end of the teleſcope, one of which muſt be unſcrewed a little, and the other ſcrewed up, till the deſired proof, the accuracy of the poſition of the teleſcope, be attained. 6. Hook the arms of the hanging levels upon the ends of the axis of the teleſcope, having previouſly placed the horizontal and horary circles level. By means of the ſmall capſtan ſcrew beneath one end of the axis, cauſe the bubble of the hanging level to occupy the middle of it's glaſs. Unhook the level, and hang it again on the axis, but in a contrary poſition, ſo that it's right-hand end may now be placed to the left. If the bubble ſtill continues to occupy the middle of the glaſs, the axis of the teleſcope is truly level or parallel to the horary circle; if not, alter the adjuſtment of the axis by the capſtan ſcrew, and of the level by it's own ſcrews, till the bubble ſtands in the middle in both poſitions. 7. Set the ſemicircle of altitude to 90°, and fix it there; ſet the declination ſemicircle to 0°, and the horary index to VI.

Direct

Direct the telefcope to a remote object. Then move the horizontal circle half round, and fet the horary index precifely at the oppofite VI. If the fame object be feen at the interfection of the crofs wires, the line of fight is rightly placed, with refpect to the horary index; if not, correct the axis of the telefcope by the fide capftan fcrew, fo that the crofs wires may cover an object half way between the former object and that laft feen. Laftly, make the horizontal and horary circles parallel to each other, and direct the telefcope to a remote object, obferving the degree and minute fhewn by the nonius of the declination femicircle. Turn the horizontal circle 180°, and the horary index likewife 180°, and obferve the fame object. If the degrees and minutes on the declination femicircle be the fame as before, the nonius is rightly placed; if not, take half the fum of the two altitudes, or depreffions, which will be the true altitude or depreffion of the object, with refpect to the horary circle; then loofen the fcrews of the declination nonius, and move it till the object feen at the interfection of the crofs wires gives the true quantity on the declination femicircle.

The problems wrought by the former inftruments, with every other in aftronomy, furveying, and menfuration, may be performed with fin-

gular accuracy by this equatorial; we ſhall only give one or two inſtances.

It is judged proper, for the benefit of perſons who have not been converſant in making aſtronomical obſervations, to ſtate here at large, ſome of the principal obſervations to be made with this equatorial, and the methods of obſerving with it.

To find the Latitude of the Place by the Sun, or any known fixed Star.

The inſtrument being adjuſted according to the directions already given, ſet the ſemicircle of altitude to 90, and when the ſun is coming near the meridian, elevate the teleſcope till the center of the ſun is exactly in the center of the braſs wires; then follow the ſun, by moving both the equatorial and declination circles, (if neceſſary) till he is at his greateſt altitude: the nonius of the declination will then give you his meridian altitude, from which ſubtract his declination, if it be north; or, add it if it be ſouth; the remainder, if north; and the ſum, if ſouth, is the height of the equator, that is, the complement of the latitude, from which ſubtract the error in altitude occaſioned by refraction, and the remainder ſubtracted from 90 degrees gives your latitude.

Example

EXAMPLE.

April 7th.— ſun's declination that day	6° 57′ 37″ north
you obſerve the meridian altitude of the ſun's center - -	45° 7′ 23″
ſubtract his declination -	6 57 37
height of the equator or co-latitude	38° 9′ 46″
ſubtract the refraction correſponding to 45° 7′ 23′ (ſun's altitude) -	5′ 54″
co-latitude corrected -	38° 8′ 52″
which ſubtracted from -	90°
gives your latitude - -	51° 51′ 8″

If inſtead of obſerving the altitude of the center, you obſerve that of the upper or lower limb of the ſun, you muſt allow for the ſemi-diameter of the ſun, which allowance you find in the nautical almanack.

N. B. The latitude may be found in the like manner by a fixed ſtar whoſe declination is known.

To find the meridian BY ONE OBSERVATION ONLY.

To do this, elevate the equatorial (or hour) circle to the co-latitude of the place, and ſet the declination circle to the ſun's declination for the

the day and hour of the day required; then move the azimuth and hour circles, both at the same time, either in the same direction, or the contrary, till you bring the center of the cross wires in the telescope exactly to cover the center of the sun: that being done, the index of the hour will give you the apparent, or solar time at the instant of observation. Thus you get the time, though the sun be at a distance from the meridian. Then turn the hour circle till the index points precisely at 12 o'clock, and lower the telescope to the horizon in order to observe some point there, in the center of your glass, and that point is your meridian mark found by one observation only. The best time of the day for this operation of finding your meridian, is three or four hours before, or three or four hours after twelve at noon.

To observe a star or planet in broad day-light, at any time when it is above the horizon.

Look in a table of right ascensions, for the time of the star's transit over the meridian.

Elevate the equatorial circle to the co-latitude of the place, and set the nonius of the declination circle to the star's declination; look into the table for the time of it's transit IMMEDIATELY PRECEDING your observation; then take the interval of time since THAT transit to the time of your observation as given by the clock,

clock, and add to it the ſtar's acceleration, correſponding to that interval of time, this ſum is the hour to which you muſt ſet the hour index of the equatorial circle, and the ſtar will then appear in the teleſcope.

The ſhorteſt way to get the interval of time between the ſtar's tranſit and the time of obſervation, is, always to ſubtract the time of the tranſit from the time of obſervation, (adding 12 hours to the clock if neceſſary) ONLY TAKE CARE, NOT TO MISTAKE MORNING HOURS FOR EVENING HOURS, or vice verſa.

EXAMPLE I.

September 30th, at 9 hours,
A. M. find Capella;

it's declination is —	45° 44′ 29″	North.
it's tranſit (by the table) is at	4*h*. 22′ 9″	A. M.
which ſubtract from time of obſervation, viz.	9	A. M.
remains interval of time ſince it's tranſit -	4 37 51	
add acceleration for 4*h*. 37′ 51″	45″	
ſet the hour index to	4 38 36	P. M.

EXAMPLE II.

May 31ſt at 2 P. M. find Arcturus;

it's declination is - 20° 22′ 30 North.

it's tranfit (by the table) that day is at $9h.\ 25' 42''$ P. M. fo that you muft take it's tranfit for May 30th, becaufe at 2 h. P. M. of May 31, it had not yet paffed the meridian that day.

—it's tranfit, May 30, is at	$9h.\ 29' 38''$	P. M.
which fubtract from the time of obfervation, viz. May 31, at	2	P. M.
remains interval of time fince it's tranfit -	4 30 22	
that is to fay, $16h.\ 30' 22''$ fince it's tranfit		
add acceleration for $16h.$ 30 22	2 42	
fet the hour index to -	$4h.\ 33' 4''$	A. M.

To find the right afcenfion, and declination of a fixed ftar, planet, comet, or the moon.

The equatorial circle being elevated as before to the complement of the latitude of the place, move the declination and equatorial circles, till the moon, ftar, or comet, is in the center of the crofs wires in the telefcope; the nonius of the declination-circle will then give you

you the declination of the ſtar, &c. and the nonius of the equatorial circle will give you the hour of the ſtar, &c. then your regulator or clock will give you the ſun's time, or hour of the day: take the difference between the ſun's time, and the ſtar's time; and if the ſtar's time is leſs than the ſun's time, add that difference to the ſun's right aſcenſion at the time of obſervation, (which you find in the nautical almanack) the ſum (rejecting 24 hours, if it exceeds that number) is the right aſcenſion of the ſtar, &c.— Again; if the ſtar's time exceeds the ſun's time, ſubtract the difference from the ſun's right aſcenſion; the remainder (adding 24 hours to the ſun's right aſcenſion, if neceſſary) is the right aſcenſion of the ſtar, &c.

EXAMPLE I.

January 31ſt, 1778.

Obſerve a ſtar whoſe time by the equatorial circle is	2h. 18′ 3″	P. M.
ſun's time as given by the regulator, viz. - -	9 44 40	P. M.
difference between the two	7 26 37	
as the ſtar's time is leſs than the ſun's, add that difference to ſun's right aſcenſion	20 57 9	
reject 24 hours from	28 23 46	
right aſcenſion of the ſtar is	4 23 46	

 It's

It's declination (by the nonius of the declination circle) is 16° 2′ 50″. North.

EXAMPLE II.

August 31ſt, 1778.

Obſerved a ſtar whoſe time by the equatorial circle is 10*h*. A. M. (that, is aſtronomically) -	22*h*. 0′ 0″
ſun's time as given by the regulator, viz. 5.55.4. A.M. (that is aſtronomically)	17 55 4
difference between the two	4 4 56
as the ſtar's time exceeds the ſun's, ſubtract that difference from ſun's right aſcenſion -	10 38 58
remains the right aſcenſion of the ſtar -	6 34 2

it's declination (by the nonius of the declination circle) is 16° 25′ 1″ South.

EXAMPLE III.

January 31ſt, 1778.

Obſerve a ſtar whoſe time by the equatorial circle is	10*h*. 50′ 0″ P. M.
ſun's time as given by the regulator, viz. - -	8 24 35 P. M.

difference

difference between the two	2	25	25
as the ſtar's time exceeds the ſun's, ſubtract that difference from the ſun's right aſcenſion	20	57	9
remains the right aſcenſion of the ſtar	18	31	44

it's declination (by the nonius of the declination circle) is 38° 35′ North.

To find the longitude at land.

Note. As there muſt be calculations made in conſequence of theſe obſervations, in order to determine the longitude required; it may be proper to apprize ſuch perſons as are not converſant in the calculations, or who do not chuſe to take the trouble to make them, that if the following obſervations be taken with care and accuracy, and immediately wrote down, the calculations for determining the longitude from thoſe obſervations, may be made by any other perſon, at any period of time thereafter, ſo as to aſcertain the longitude ſought with the ſame preciſion, as if the calculations had been made at the moment of obſerving.

To find the longitude wanted. Obſerve the difference of the right aſcenſion of two celeſtial bodies; for inſtance, of the moon, and a known fixed ſtar, at any given time, either on, or out of

 the

the meridian, and from that difference infer the moon's right afcenfion at the moment of obfervation. That being obtained, find what is the precife time, at any place whofe longitude is well afcertained; for inftance, at Greenwich, when the moon has that right afcenfion, which you have now obferved. The difference between that time at Greenwich, and time with you, is the difference of longitude, in time, between Greenwich and your place of obfervation, which is eaft of Greenwich, if the time with you be later than the time at Greenwich; and is weft of Greenwich, if the time with you be earlier than that of Greenwich.

The equatorial being properly adjufted in all it's parts, and fet to the co-latitude of the place, proceed according to the following examples.

EXAMPLE I.

Where the moon and a known fixed ftar are each of them obferved on the meridian.

June 26th, 1779. Arcturus obferved on the meridian at - - 7*h*. 43′ 49″ P. M. (mean time)

and the moon's weftern limb at - 10*b*. 30′ 16″ P. M. (mean time)

EXAMPLE

EXAMPLE II.

When the ſtar is obſerved, out of the meridian, on any hour circle whatever; and the moon is likewiſe obſerved, out of the meridian, on the ſame, or on any other hour circle whatſoever.

June 28th, 1779. Arcturus obſerved on a horary circle, 1*h*. 55′ 52″ weſt of the meridian by the inſtrument, at	9*h*. 31′ 49″ P. M. (mean time)
moon's weſtern limb obſerved on another horary circle 1*h*. 10′ eaſt of the meridian by the inſtrument, at	10*h*. 56′ 16″ P. M. (mean time)
ſuppoſed difference of longitude in time, weſt of Greenwich	0 12′ 0″

latitude of the place of obſervation 56° 35′ North.

Nothing more is required from the obſerver than the two data in the firſt example, or the four data in the 2d example; from either of which, the longitude of any place at land may be deduced by calculation.

F I N I S.

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Small pocket microſcopes, from 6s. to	8	13	6
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Concave and convex mirrors, from 7s. 6d. to	18	18	0
Cylindrical ditto, from 1l. 1s. to	13	13	0

Geographical and Aſtronomical Inſtruments.

PRICES OF GLOBES.

	£.	s.	d.
28 inches diameter mounted in mahogany frames ——— ———	52	10	0
28 ditto frames carved and ornamented			
18 ditto mounted in the common manner	6	6	0
18 ditto mounted in the common manner in mahogany frames ———	8	8	0
18 ditto mounted in the beſt manner, in ſtained frames — ———	10	10	0
18 ditto mounted in the beſt manner, in mahogany frames ———	12	12	0

18 inches

	£.	s.	d.
18 inches diameter, mounted in the beft manner, in carved frames ——	16	16	0
16 ditto mounted in the common manner	6	6	0
12 ditto mounted in the common manner	3	3	0
12 ditto mounted in the common manner, in mahogany frames —— ——	4	4	0
12 ditto mounted in the beft manner, in ftained frames ——	5	15	6
12 ditto mounted in the beft manner, in mahogany frames ——	7	7	0
9 ditto mounted in the common manner	2	2	0
9 ditto mounted in the beft manner	4	4	0
6 ditto mounted in the beft manner	3	3	0
3 ditto mounted in the beft manner	1	11	6
3 ditto for the pocket ——	0	10	6
An armillary dialling fphere ——	40	0	0
An armillary fphere, fhewing at one view the real and apparent motion of the heavens	31	10	0
An armillary fphere, with a planetarium within it	31	[illegible]	0
Plain armillary fpheres			
A manual planetarium and tellurian ——	3	[illegible]	6
A new inftrument for illuftrating the phænomena of the feafons —— ——	4	10	0
A ditto for illuftrating the phafes of the moon, and the caufes of eclipfes ——	4	10	0
A manual planetarium —— ——	2	2	0
(The three laft-mentioned inftruments are thofe reprefented in plates V. XV. and XVI. of my aftronomical effays)			
A planetarium with wheel-work, by which the order and motion of the planets, their fituation with refpect to the earth at different times, and the reafon of their appearing to be fometimes ftationary, and to move at other times in contrary directions, are rendered obvious to the eye	7	17	6
A tellurian and lunarium for illuftrating the phænomena of the earth and moon, and forming a proper companion for the former			
(The tellurian and lunarium may be combined together, or feparate)			
A correct and elegant planetarium, lunarium, and tellurian, (fee plate XIX. of my aftronomical effays) —— —— ——	18	18	0
Ditto with the diurnal motion to the earth	24	0	0

The

	£.	s.	d.
The moſt complete planetarium, tellurian, and lunarium, plates XVII. and XVIII. -	36	15	0
Orreries, from 18l. 18s. to —	1000	0	0
A ſmall quadrant, with an horizontal and vertical motion, for the inſtruction and amuſement of young people — —	0	16	0
A ditto framed in braſs, more accurately made and graduated — — —	2	12	6
A ſmall equatorial, being at once an accurate univerſal dial, and a portable obſervatory; with it a great number of curious and intereſting problems may be ſolved, and any perſon ſoon rendered maſter of the elements of practical aſtronomy — — —	8	8	0
Ditto on a larger ſcale, with a teleſcope, and more adjuſtments — —	26	5	0
Complete equatorial inſtruments, from 50 gs. to	500	0	0
Tranſit inſtruments, aſtronomical quadrants, circular inſtruments, according to their ſizes, the variety and accuracy of their adjuſtments.			

Mathematical Inſtruments, for Geometry, Drawing, &c.

Plain compaſſes for meaſuring lines, from 1s to	0	5	0
Drawing compaſſes with moveable points, from 5s 6d. to —— ——	3	3	0
Drawing pens, from 1s. to ——	0	5	0
Bow compaſſes for deſcribing ſmall circles, from 3s. to —— —— —	0	5	0
Hair compaſſes for taking extents with accuracy	0	7	6
Beam compaſſes for deſcribing large circles, laying down diviſions, &c.			
Triangular compaſſes for transferring three points at once from any plan or drawing, from 18s. to	1	1	0
Proportionable compaſſes for diminiſhing plans or drawing in any aſſigned proportions —	1	11	6
Elliptical compaſſes with friction rollers, for drawing ellipſes — —	4	4	0

Elliptical

	£.	s.	d.
Elliptical compaſſes on a different conſtruction, anſwering at the ſame time the purpoſes of beam and calliper compaſſes ——	4	4	0
Spiral compaſſes for deſcribing ſpirals, anſwering alſo as beam and elliptical compaſſes, from 6l. 6s. to —— ——	11	11	0
Parallel rules of various conſtructions			
A new-invented parallel rule, which for facility in application, and accuracy, exceeds any other kind, from 8s. 6d. to —— ——	1	1	0
Ditto with a protractor			
An inſtrument for drawing lines inclined in a given angle to each other, though the angular point is at an immenſe diſtance, a rule exceedingly uſeful in perſpective			
Various inſtruments for the purpoſe of dividing lines, or transferring diviſions on paper			
A cyclograph, or an inſtrument by which circles may be deſcribed, from 4 or 6 inches radius to one as large as the orbit of the Georgium Sidus	6	6	0
Plain ſcales and ſectors of different ſi es			
Square protractors, ſemicircular and circular			
Pocket caſes of drawing inſtruments, from 7s. 6d. to	5	15	6
Magazine, or complete collection of drawing inſtruments, at 11l. 11s. at 17l. 17s. and from thence to —— ——	50	0	0
Perſpective compaſſes for aſcertaining the relative proportion of objects — ——	0	18	0
Dr. Hirſt's inſtrument for drawing in perſpective	5	5	0
A new invented inſtrument for the ſame purpoſe, which will facilitate the operations of the artiſt, and greatly aſſiſt beginners			
An inſtrument for facilitating drawing from nature, by aſcertaining a number of points			
Concave lenſes with ſquares for eye drafts			
Drawing glaſſes, or glaſſes with a ſight to aſſiſt draftſmen			
Pantographers for copying, reducing, and enlarging drawings, from 2l. 12s. 6d. to ——	6	6	0

Surveying

Surveying Inſtruments.

	£.	s.	d.
Caſes of drawing inſtruments			
Parallel rules			
Plotting ſcales			
Sets of plotting ſcales			
A new invented parallel rule, with plotting ſcales			
A parallel rule and protractor			
A plotting ſcale, in form of a beam compaſs			
Protractors for laying down angles			
Ditto with a nonius and moveable limb —	2	12	6
Ditto rendered more accurate, as the limb is made to move with a tooth and pinion —	4	14	6
Meaſuring wheels ——— ———	6	16	6
Pedometers for meaſuring a given diſtance in walking.			
Meaſuring chains of 50 and 100 feet			
Gunter's chain ——— ———	0	7	6
Tape boxes, according to the length			
Surveying croſs or ſquare ———	1	11	6
Plain tables, with an index and ſights; by theſe the plan is taken on the ſpot, and does not require a future protraction ——— ———	3	13	6
Beighton's improved plain table, with an index of a peculiar make; in this inſtrument the line of ſight is always over the center of the table, the ſtation lines are alſo drawn parallel to thoſe meaſured on the ground ——— ———	14	14	0
Theodolites, or inſtruments for meaſuring angles, diſtances, &c. are made in various ways, ſome being more ſimple and portable, others more accurate, and with a greater number of adjuſtments			
Theodolites, with four plain ſights, and a compaſs box, from 5l. 5s. to ———	5	15	6
A ſmall theodolite, with teleſcopic ſights and vertical arch ——— ——— ———	9	9	0
A larger ditto, in which the limb of the theodolite is made to ſerve occaſionally the purpoſe of a protractor ——— ———	14	14	0
A ditto of the ſame ſize, on a different conſtruction, the vertical arch being affixed to a long axis; the limb does not ſerve for a protractor ———	14	14	0
A larger ditto, like the preceding, only moving with rack-work ——— ———	21	0	0

	£.	s.	d.
The lateſt improved theodolite, with double teleſcope, and every requiſite adjuſtment	31	10	0
Circumferenters, the principal inſtrument uſed in America, from 2l. 2s. to ——	4	14	6
An improved circumferenter, ſo contrived that the operator need not reſt the truth of his work entirely on the needle; it may be alſo uſed to take altitudes			
Air or ſpirit levels with teleſcopic ſights, from 4l. 14s. 6d. to —— ——	12	12	0
Air or ſpirit levels with plain ſights ——	1	11	6
Station ſtaves with ſliding vanes for levelling	1	16	0
A ſmall ſurveying compaſs, with ſights, a nonius diviſion, and three-legged ſtaff ——	4	14	6
A ſmall ſurveying compaſs and ſingle ſtick	2	2	0
(The two foregoing inſtruments are portable and light, and may be put with eaſe in the pocket)			
Miners compaſſes, uſed for carrying on works under-ground, from 10s. 6d. to ——	1	1	0
Ditto with a ſmall teleſcope fixed to one ſide	1	11	6
Green's teleſcope and tangent board, for meaſuring diſtances at one ſtation: (it is obvious, that on the meaſuring of a ſtrait line with accuracy, the whole buſineſs of ſurveying depends; Mr. Green's method is certainly more expeditious than any other, and is not liable to objections which may be made to them)			
Optical ſquare, a ſmall inſtrument for ſurveying by right angles; it requires no ſtaff, and may be eaſily corrected or adjuſted — ——	1	16	0
An optical inſtrument for determining with accuracy when objects are in a ſtrait line —	1	7	0

Military Inſtruments.

Gunners levels or perpendiculars
Gunners callipers
Beam callipers
Shot guages
Shell ditto
Gunners quadrants with a plummet
Ditto with a level

Ditto

	£.	s.	d.
Ditto with an adjufting fcrew			
Ditto and perpendicular combined together			
General Williamfon's inftruments for howitzers, mortars, &c.			
Surveying compaffes, furveying croffes, cafes of inftruments, telefcopes, plain tables, theodolites, &c.			
A complete apparatus for an officer, in a box	21	0	0

Inftruments for Navigation.

Cafes of inftruments, and telefcopes of different kinds, fizes, and prices			
Night telefcopes, from 1l. 11s. 6d. to ——	2	2	0
Opera glafs for the fame purpofe ——	1	11	6
A telefcope with an eye-glafs micrometer, for determining the diftance of a fhip at fea			
Hadley's quadrants in mahogany frames --	2	2	0
Ditto in black ebony frames ——	3	3	0
Hadley's fextant in wood ——	6	16	6
Ditto in brafs, on the moft improved plan, from 11l. 11s. to —— ——	15	15	0
Knight's fteering compafs, with improvements	2	12	6
Knight's azimuth ditto ——	5	15	6
Ditto on friction wheels ——	10	10	0
Marine barometers; by thefe ftorms have been foretold at fea fome hours before they happened			
Circular inftruments, to anfwer the purpofe of the fextant			
Dipping needles, from 12l. 12s. to —	31	10	0

Inftruments for Electricity.

A fmall electrical machine, with a felect apparatus	8	8	0
An electrical machine and medical apparatus in a box; the machine is mounted in a plain but ftrong manner, and fo as to act with power; the apparatus is the moft convenient and fimple hitherto contrived for medico-electrical purpofes	6	16	6

Ditto

Q q

	£.	s.	d.
Ditto with an additional apparatus lately contrived for more easily giving partial shocks —	7	17	6
Improved electrical machines, from 3l. 13s. 6d. to	40	0	0
Electrical batteries, from 2l. 12s. 6d. to			
Electrical jars of different sizes			
Ditto with an electrometer affixed to them	0	18	0
Medical bottles, with a tube for qualifying the shock — — —	0	7	6
Ditto mounted with a discharging rod, and an electrometer, on an improved plan, for giving the electric shock — —	1	1	0
Directors with glass handles for medical purposes	0	10	6
Jointed dischargers with glass handles —	0	10	6
Plain discharging rods — —	0	3	0
An universal discharger and press —	1	11	6
Kinnersly's electrical thermometer —	1	1	0
Quadrant electrometer —	0	10	6
Cavallo's atmospheric electrometer, from 15s to	1	1	0
Ditto, with additions by De Saussure —	1	11	6
Bennet's gold leaf electrometer —	0	18	0
An apparatus for making Canton's and Wilson's experiments on electric attraction, &c.			
Compound apparatus, fig 49, plate III. of my essays on electricity; by this apparatus a great number of neat and satisfactory experiments may be performed — —	3	3	0
Ditto without the exhausted flask and conductor	1	11	6
Leyden vacuum — —	0	10	6
Luminous conductors — —	1	1	0
Spiral tubes, from 4s. 6d. to —	0	10	6
Coloured spirals — —	0	9	0
Sets of spirals, see plate V. fig. 98, of my essays on electricity — —	1	11	6
Luminous words, from 10s 6d. to —	1	11	6
Spotted bottle — —	0	9	0
Belted bottle, plate III. fig. 46 —	1	1	0
Double bottle, a pleasing and useful part of an electrical apparatus, to gain a clear idea of the Franklinian theory —	0	18	0
Plates and stand for dancing images, pith images, and pith balls			
An artificial spider			
A small head with hair			
An electrical pistol for inflammable air —	0	7	6
Ditto mounted in sets			

An

	£.	s.	d.
An electrical cannon for gunpowder			
A thunder houſe ——— ———	0	6	6
Ditto with a drawer ———	0	8	6
A powder houſe, fig. 89, plate V. ———	0	16	0
A pyramid, fig. 90, plate V. ———	0	15	0
Nicholſon's revolving doubler ———	3	3	0
A bone ball, and a ball of box wood fitted on braſs wires			
Electric flyer and points			
A plain ſet of bells, fig. 17, plate II. —	0	9	0
Five bells mounted on a ſtand, fig. 18, plate II.	0	18	0
A ſet of muſical bells, fig. 19, plate II.	1	7	0
Magic picture ——— ———	0	10	6
Electrical ſtools, from 8s 6d. to ———			
An electrophorus, from 10s. 6d. to — —			

Apparatus for Experiments on Magnetiſm.

An apparatus for explaining the principal phænomena of magnetiſm, from 3l. 3s to	15	15	0
Magnets			
Small compound magnets			
Horſeſhoe magnets			
Compound ditto, from 15s to ———	21	0	0
Dipping needles from 12l. 12s. to —	31	10	0
Variation compaſſes, from 2l. 12s. 6d. to	21	0	0

Inſtruments for Experiments on Pneumatics.

A ſmall ſingle-barrel air-pump ———	2	12	6
A ſmall double-barrel ditto ———	4	14	6
A larger ditto ——— ———	6	16	6
A table air pump ——— ———	10	10	0
The American double barrelled air pump, the lateſt improvement on this inſtrument, in which the air receives no impediment from the action of valves or cocks, exceeding Smeaton's in accuracy and ſimplicity, and far ſuperior in both reſpects to ſeveral later contrivances			

	£.	s.	d.
A condenſing engine; this may be, if deſired, combined with the former, but the rational and practical experimentaliſt will find many advantages in having them detached from one another			

Apparatus for an Air Pump.

	£.	s.	d.
The magdeburg hemiſpheres, from 12s. to	1	11	6
A flat plate and collar of leathers for placing on open receivers ——— ———	0	15	6
Guinea and feather apparatus, for experiments on the reſiſtance of the air, from 18s. to	1	11	6
A ſet of mills for ditto ———	1	11	6
A ditto on a better conſtruction ——	4	4	0
Bell apparatus, for ſhewing that a vacuum does not communicate ſound —— ——	0	5	6
Ditto on a better conſtruction			
Ditto with wheel-work, by which the bell may be put in motion or ſtopped at pleaſure —	3	13	6
A new apparatus for ſtriking flint and ſteel in vacuo			
An apparatus for firing gunpowder in vacuo			
A copper bottle, beam and ſtand, for weighing of air	2	16	0
A box, bladder, and lead weights, to ſhew the elaſtic power of the air ——— ———	0	15	6
Ditto on an improved plan ———	0	18	0
A model of a pump, illuſtrating at the ſame time the nature of pumps, and proving that there is no ſuch thing as ſuction ———	1	5	0
A ſmall receiver and plate, which clearly evinces that receivers are kept on the pump by preſſure, not ſuction ——— ———	0	12	0
A filtering cup ——— ———	0	5	6
A plate and piece of wood ———	0	4	6
(The two laſt articles are for ſhewing the poroſity of vegetables)			
The torricellian experiment			
Fountain in vacuo —— ———	0	5	6
Ditto on a different conſtruction ———	0	18	0
Lungs glaſs —— ——	0	5	6
Ditto on a different conſtruction			
A ſingle transferer plate and pipe for a fountain	0	15	6

A double

	£.	s.	d.
A double transferer, for communicating a vacuum from one receiver to another ——	3	3	0
A burnt air pipe, for experiments on infected air	0	18	0
An apparatus to illuſtrate the lateral preſſure of the air			
Breaking ſquare and cage			
A ſmall bladder and lead weight			
A ſmall ballance beam and ſtand ——	0	7	6
Ditto on an improved conſtruction			
Receivers of different ſizes			

Meteorological Inſtruments.

A plain portable barometer ——	2	2	0
Ditto with a thermometer ——	3	3	0
A plain barometer, covered frame and glaſs door	2	12	6
Ditto with a thermometer ——	3	13	6
A barometer with a long cylindric thermometer	4	4	0
A ditto with ditto, and De Luc's hygrometer	7	7	0
A barometer and thermometer, with a guage, the indexes moving by rack-work ——	5	15	6
A barometer for meaſuring the altitude of mountains, &c.			
Marine barometers			
Diagonal, wheel, and ſtatical barometers			
Fahrenheit's thermometers, from 1l. 1s. to	2	12	6
Ditto for botanic purpoſes ——	0	18	0
Ditto for the brewery ——	1	1	0
De Luc's hygrometer; theſe are the only inſtruments by which comparative obſervations can be made on the dryneſs and moiſture of the air, from 3l. 3s. to —— ——	7	7	0
Rain guages			
Dr. Lind's wind guage			
Hygrometers with the beard of the wild oat	0	10	6
Fontana's eudiometer for aſcertaining the purity of the air —— ——	2	5	0

Inſtru-

Inſtruments for illuſtrating the Mechanic Powers, the Laws of Motion, &c.

	£.	s.	d.
A conciſe apparatus for illuſtrating the nature of the ballance, the pulley, the different kinds of levers, the inclined plane, the wheel and axle, the ſcrew, a compound engine, and a compound lever; alſo, a double cone to move up an inclined plane, and other pieces to ſhew the properties of the center of gravity, from 21l. to	26	5	0
A ditto on a more enlarged ſcale			
Atwood's apparatus for demonſtrating with accuracy the laws of accelerated and retarded motion. It is one of the moſt pleaſing and ſcientific inſtruments in mechanics, as well from the variety of experiments that may be made with it, as the accuracy with which they are performed	26	5	0
A machine for illuſtrating the theory of central forces; in this machine the times are marked by ſound, the ſpaces are ſhewn by an index, the errors ariſing from friction are ſo far leſſened as to be ſcarcely ſenſible ———	31	10	0
Pullies of various combinations and conſtructions			
A ſmall carriage, inclined plane, wheels of different ſizes, &c. for experiments on wheel carriages			
Roberval's paradoxical ballance			
Cycloidal lever, ſee Emerſon's Mechanics, prop. 20, 25.			
Compound ſteelyard			
An apparatus for experiments on colliſion			
Ditto for illuſtrating the compoſition and reſolution of motion			
Pyrometers on various conſtructions			

With many other articles and models for experiments on friction, pendulums, &c. too numerous to be comprized in a ſmall catalogue

Inſtru-

Inſtruments for Experiments in Hydroſtatics and Hydraulics.

	£.	s.	d.
Hydroſtatic ballances, from 2l. 2s. to —	10	10	0
Nicholſon's improved hydrometers, for aſcertaining the ſpecific gravity of bodies			
Ditto for examining of coin			
A conciſe apparatus for experiments on hydroſtatics	21	10	0
An apparatus for ſhewing that fluids have weight			
Ditto for ſhewing that the particles of fluids exerciſe their preſſure independently one of the other			
Ditto to ſhew that fluids preſs in every direction			
Ditto to demonſtrate the lateral preſſure of fluids			
Ditto to ſhew that, *cæteris paribus*, the preſſure of fluids is as their perpendicular height			
The hydroſtatic paradox			
The hydroſtatic bellows			
Apparatus for illuſtrating the laws of preſſure and equilibrium between heterogeneous fluids			
Ditto for illuſtrating the action of fluids upon bodies immerſed in them			
An apparatus for experiments on ſpouting fluids			
Hydrometers for proving ſpirits, from 1l. 11s. 6d. to	4	14	6
An apparatus for making experiments on capillary tubes			
The model of the diving bell			
A glaſs model of the lifting pump			
A ditto of the lifting and forcing pump			
Hiero's fountain in copper japanned			
Ditto double			
Fountain of command			
A japanned copper fountain to act by condenſed air with a variety of jets			
Apparatus for experiments on ſyphons.			

Plate I.

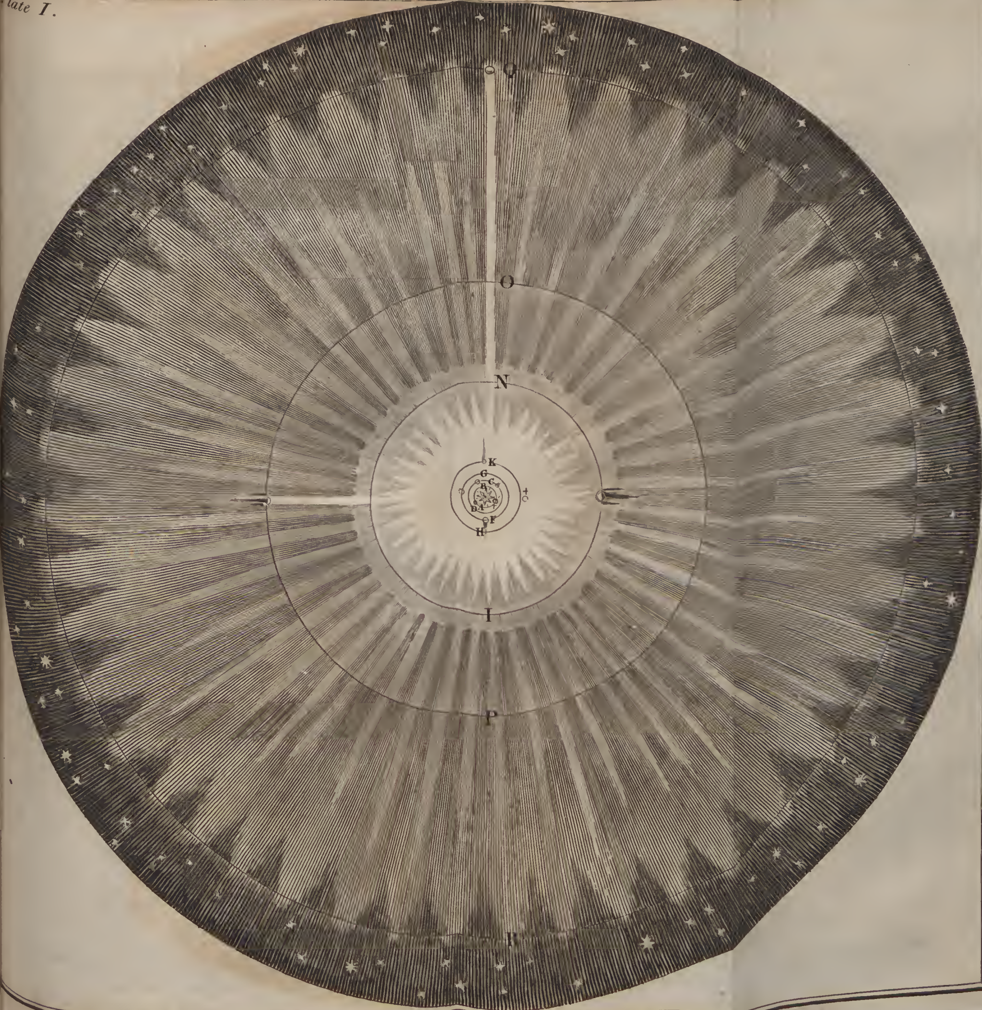

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PLATE II.

Fig. 1.

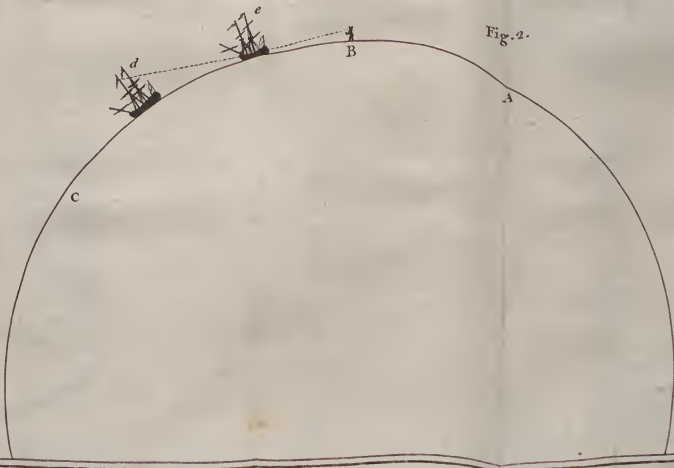

Fig. 2.

...ine del. Jn. Lodge sc.

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Fig. 1.

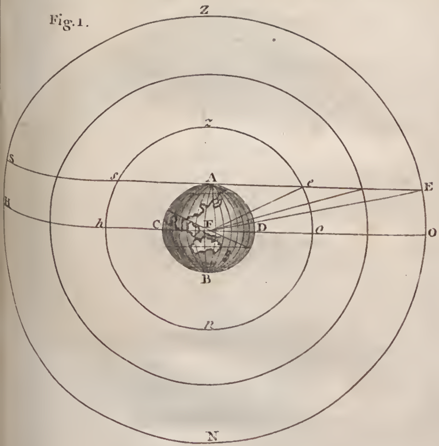


Fig. 2.

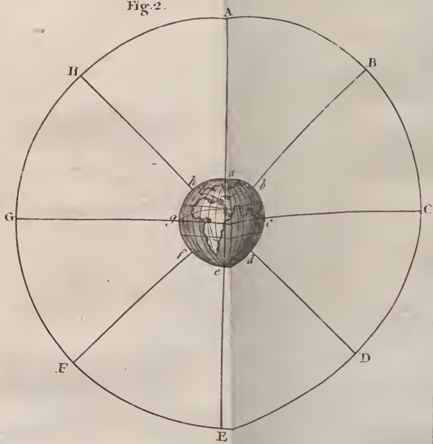


Fig. 3.

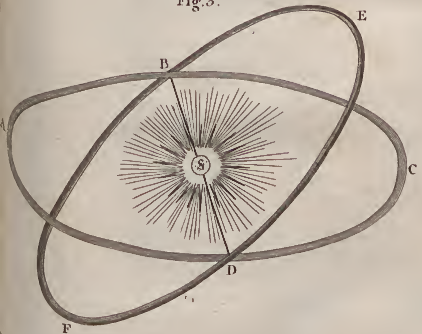
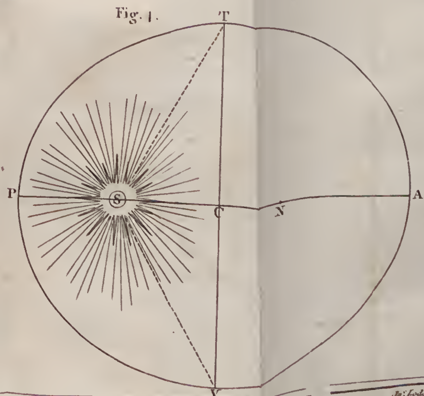


Fig. 4.



Milne del. Jn. Lodge sc.

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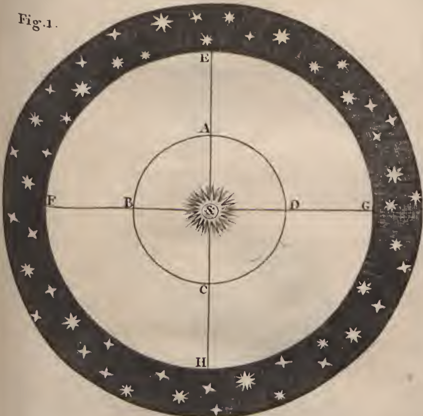
Fig. 1.



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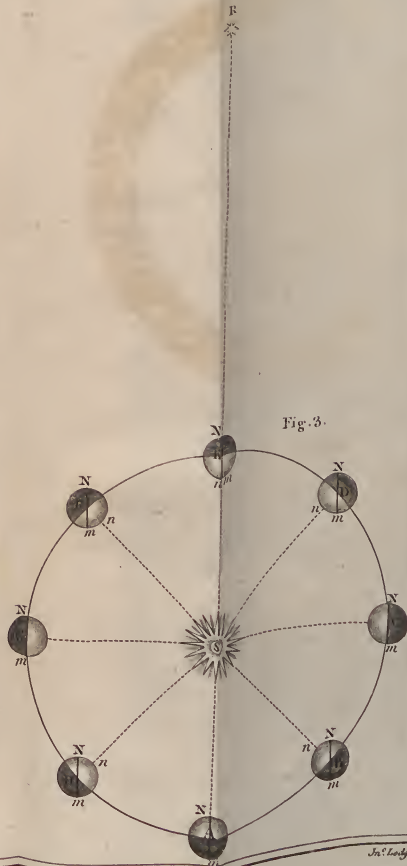

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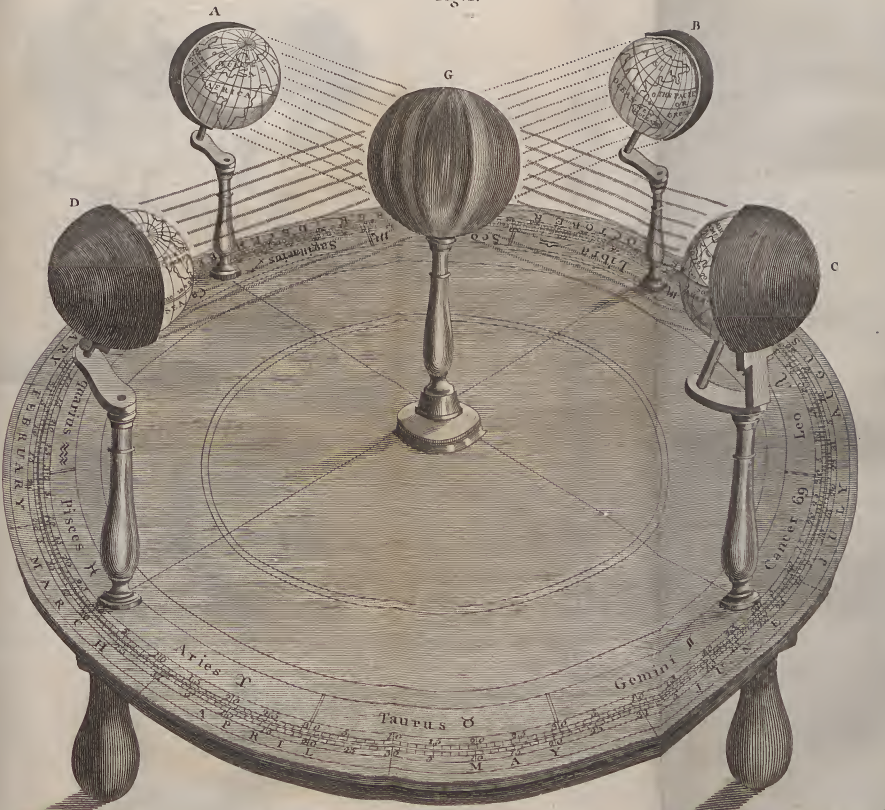

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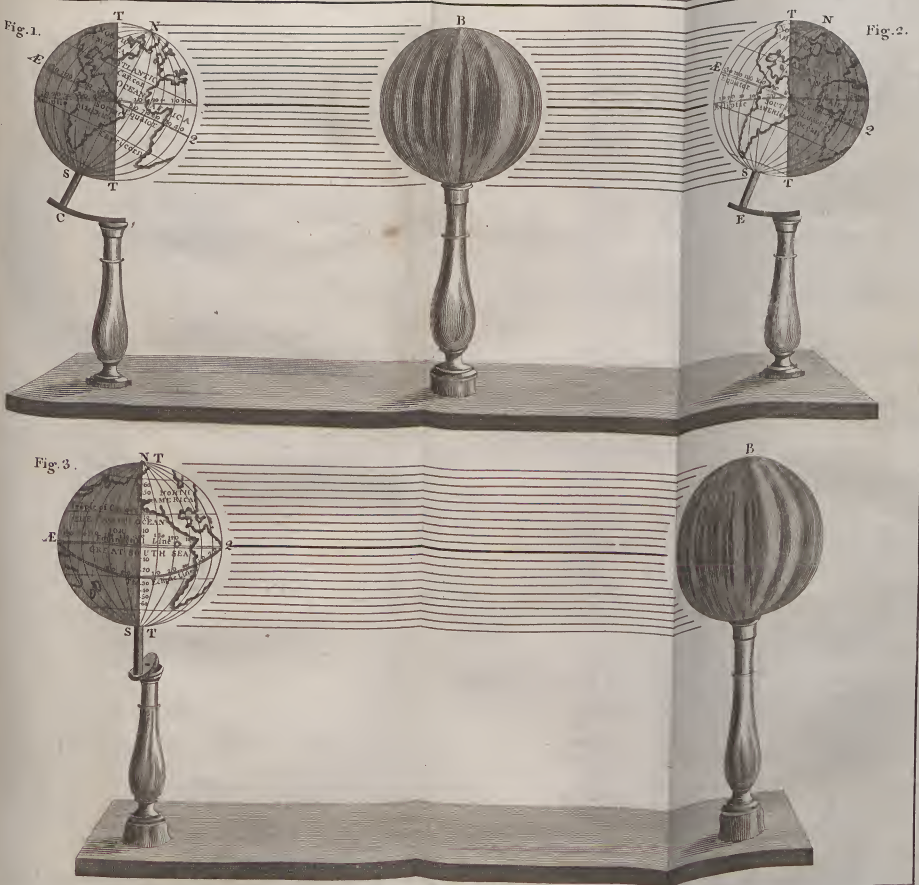

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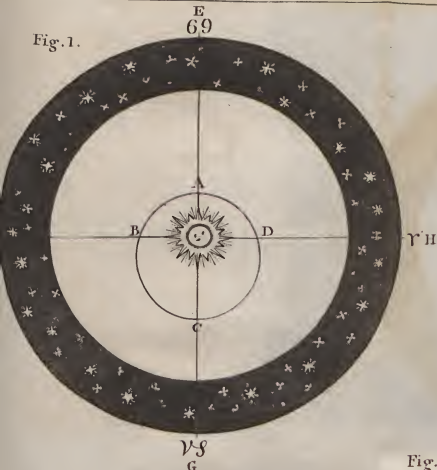

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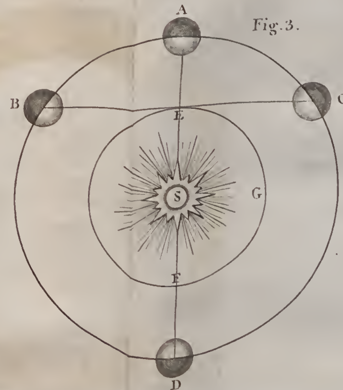

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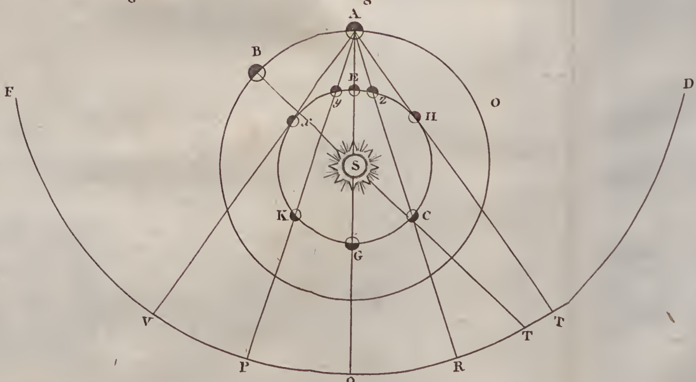

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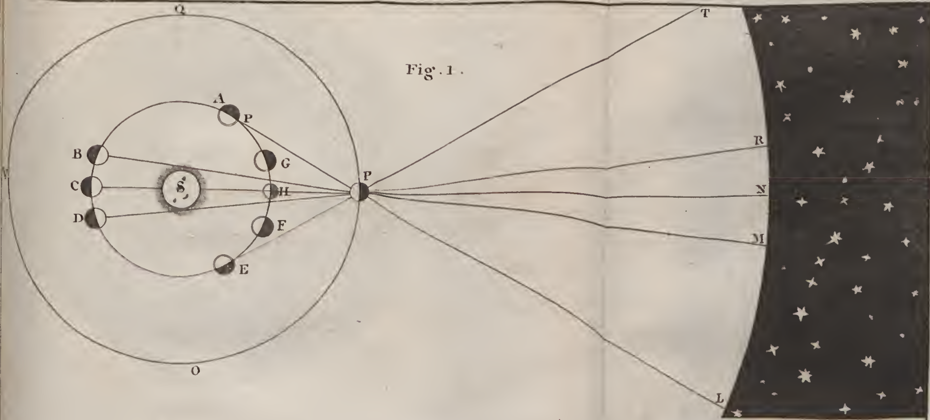

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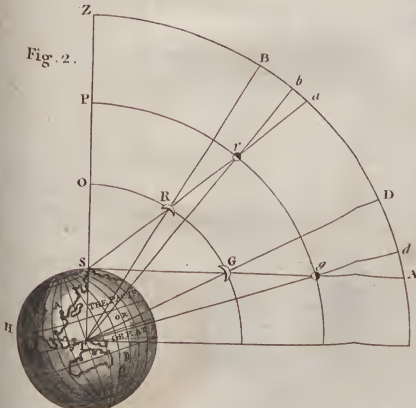

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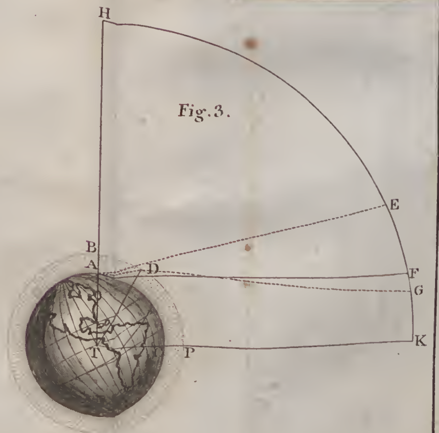

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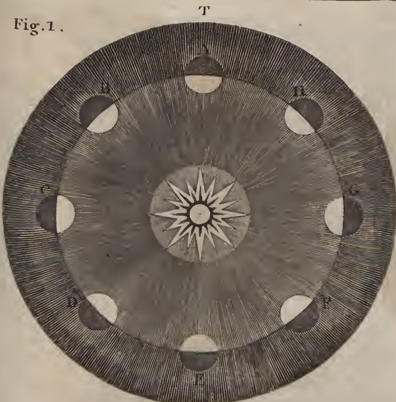

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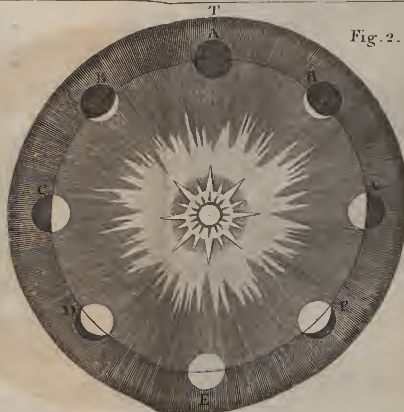

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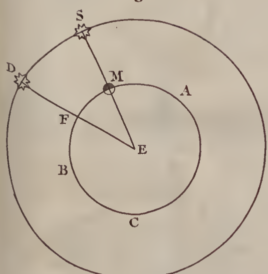

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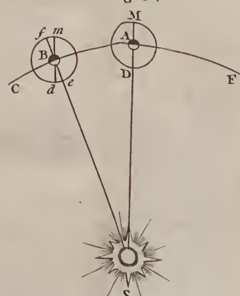

Fig. 7.

Fig. 6.

Fig. 5.

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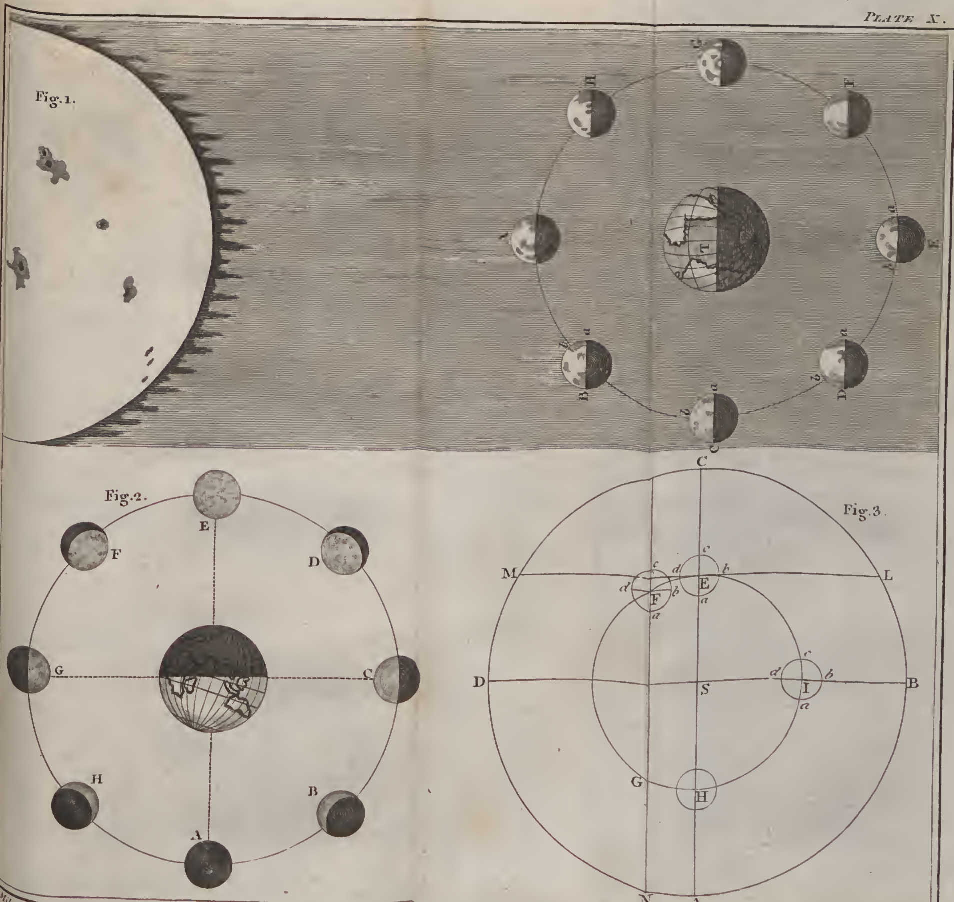
PLATE X.



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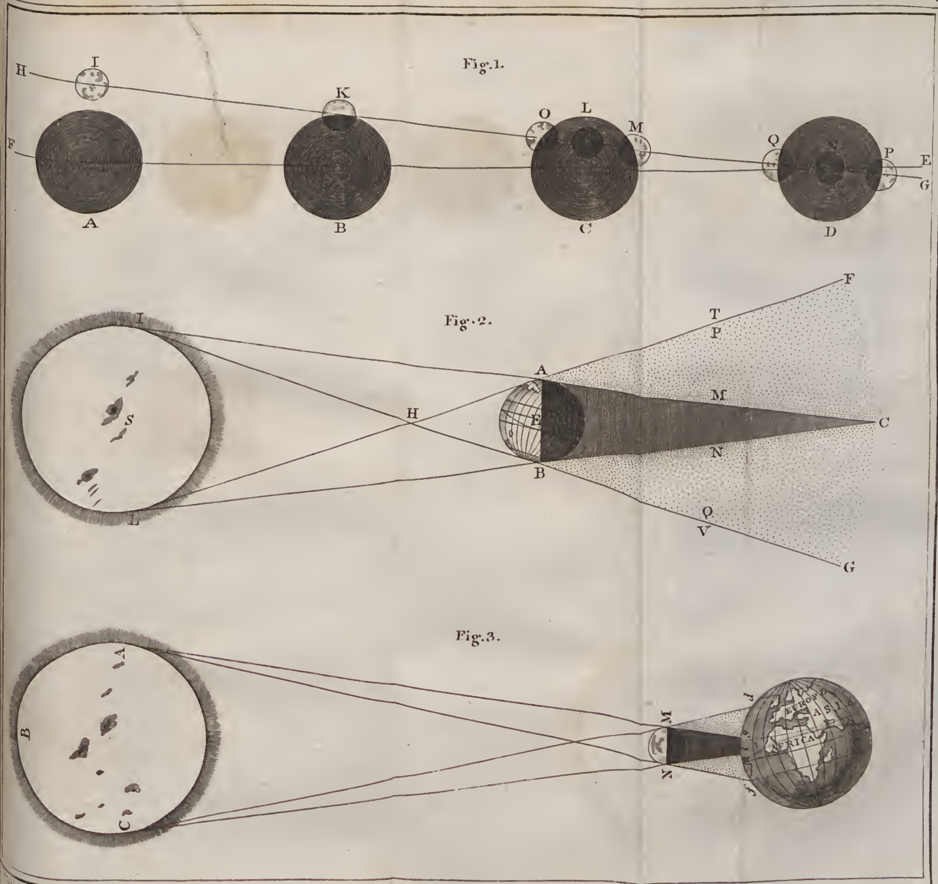

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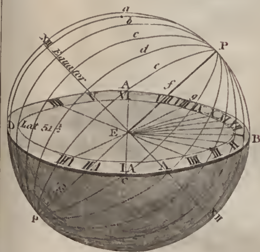

Fig. 2.

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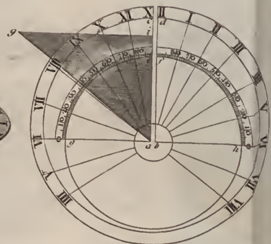

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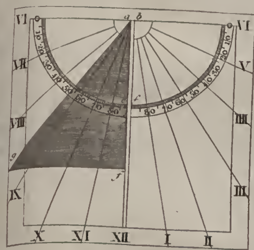

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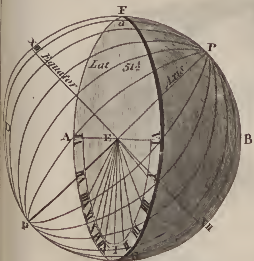

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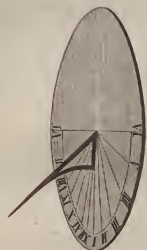

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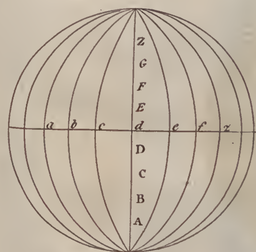

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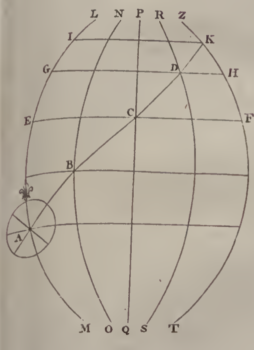

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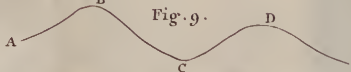

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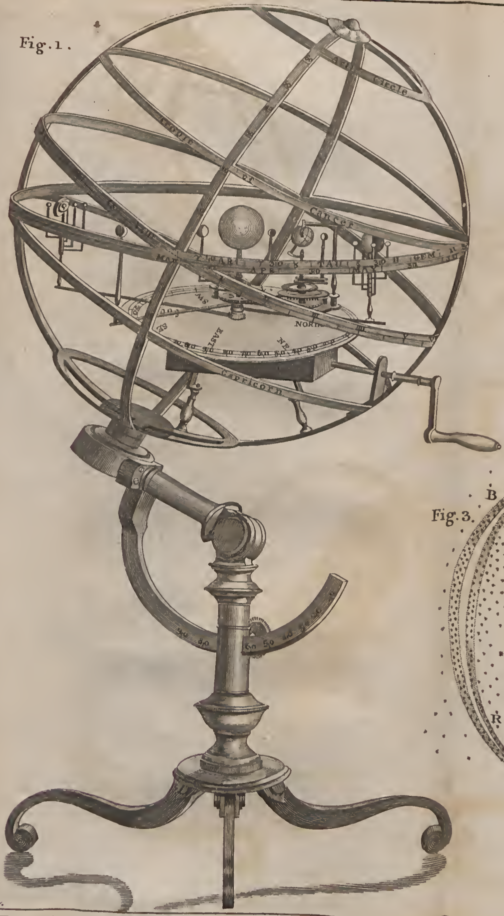

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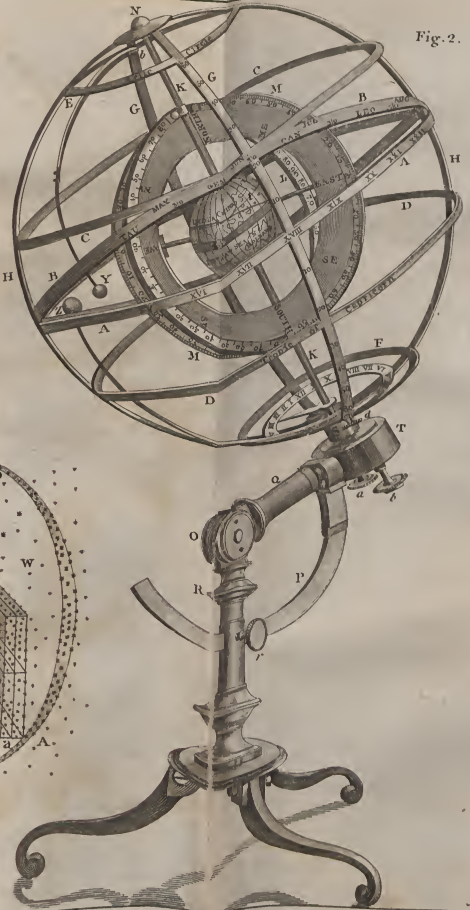

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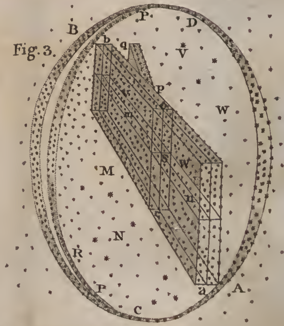

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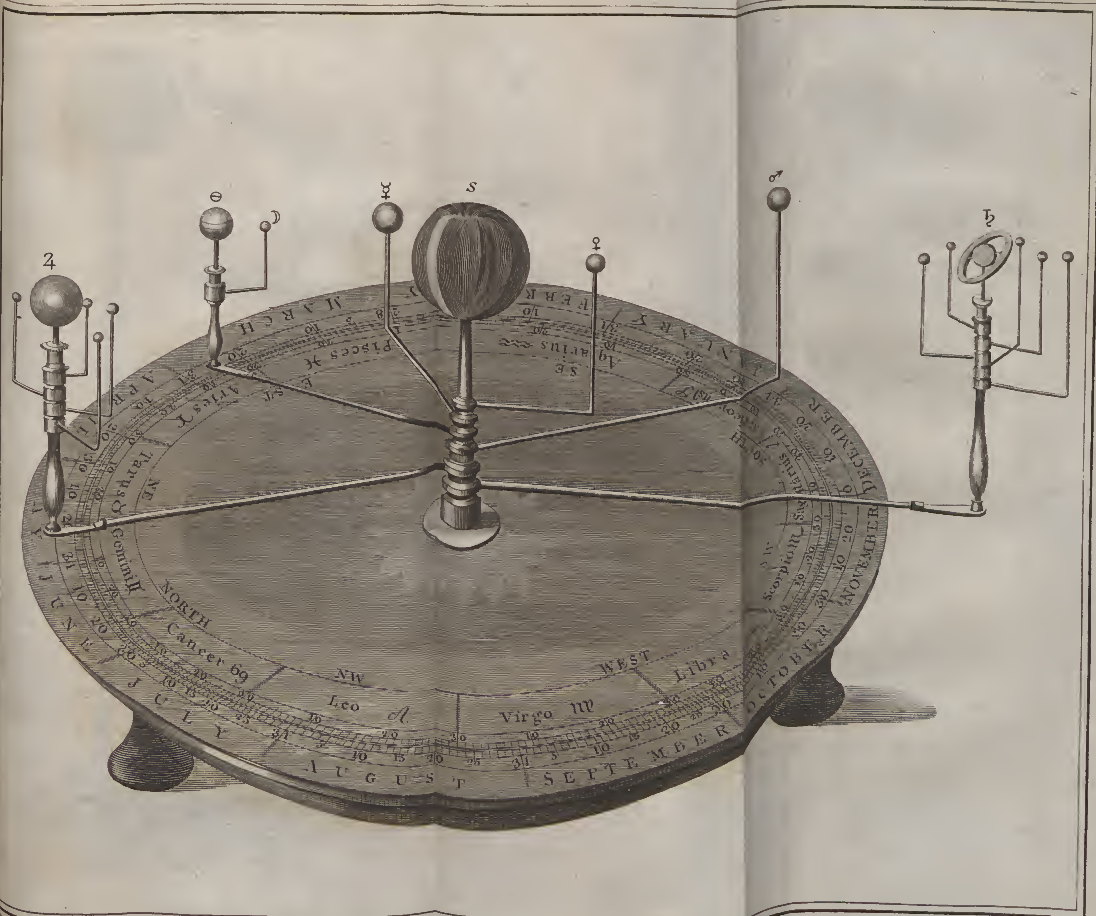

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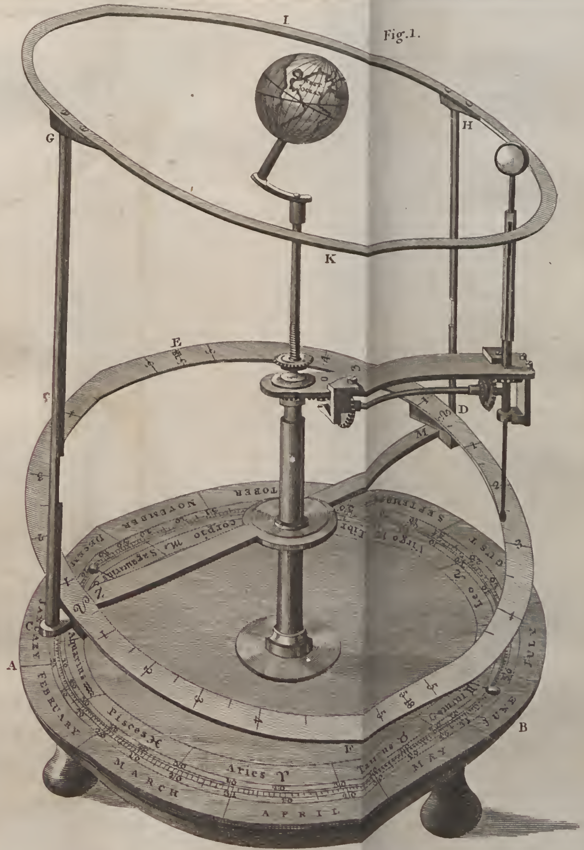
Fig. 2.



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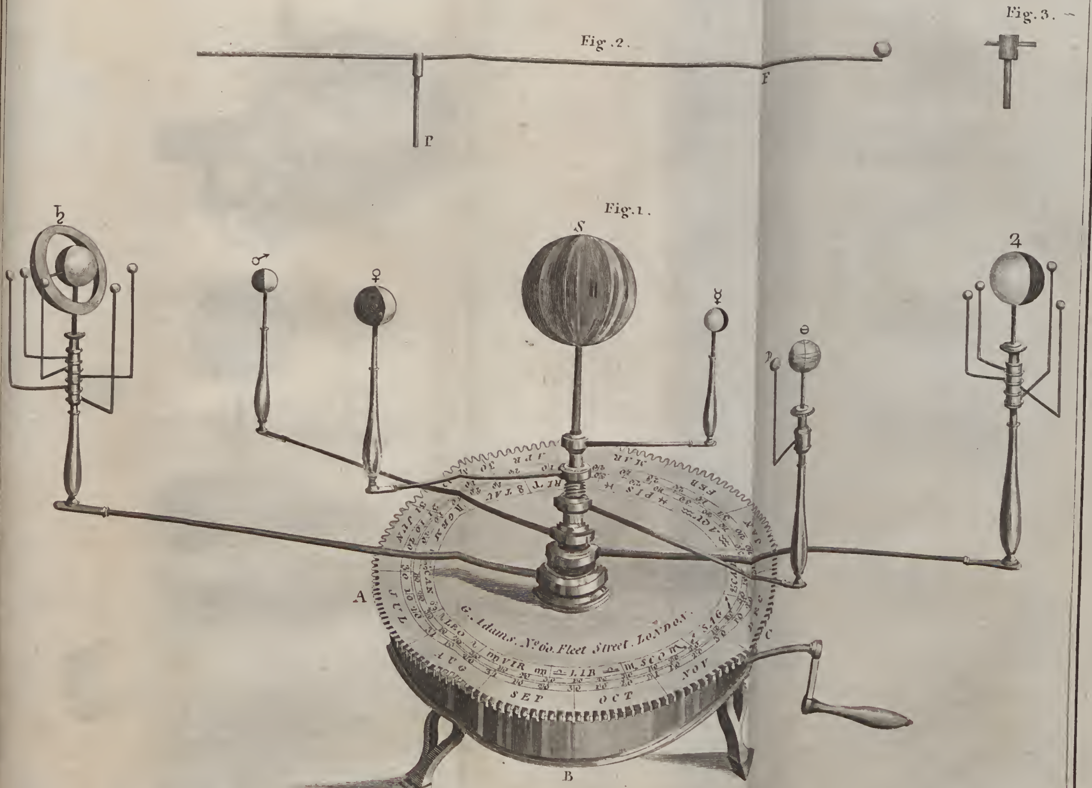

J. Milne del.

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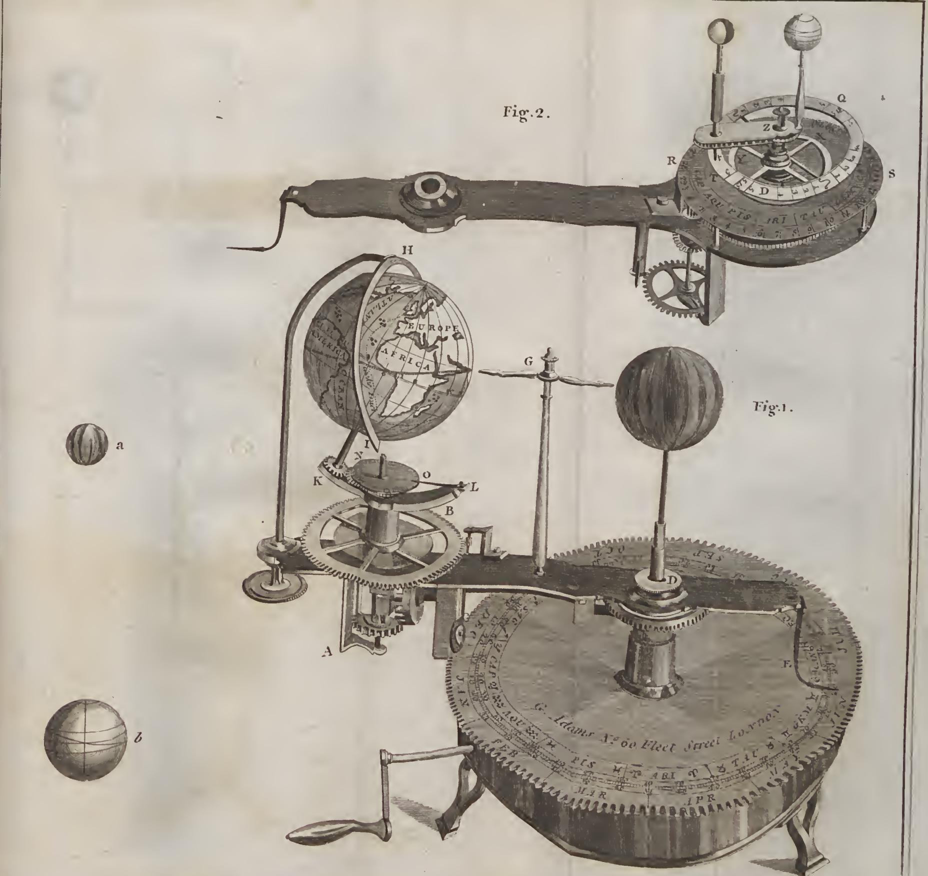

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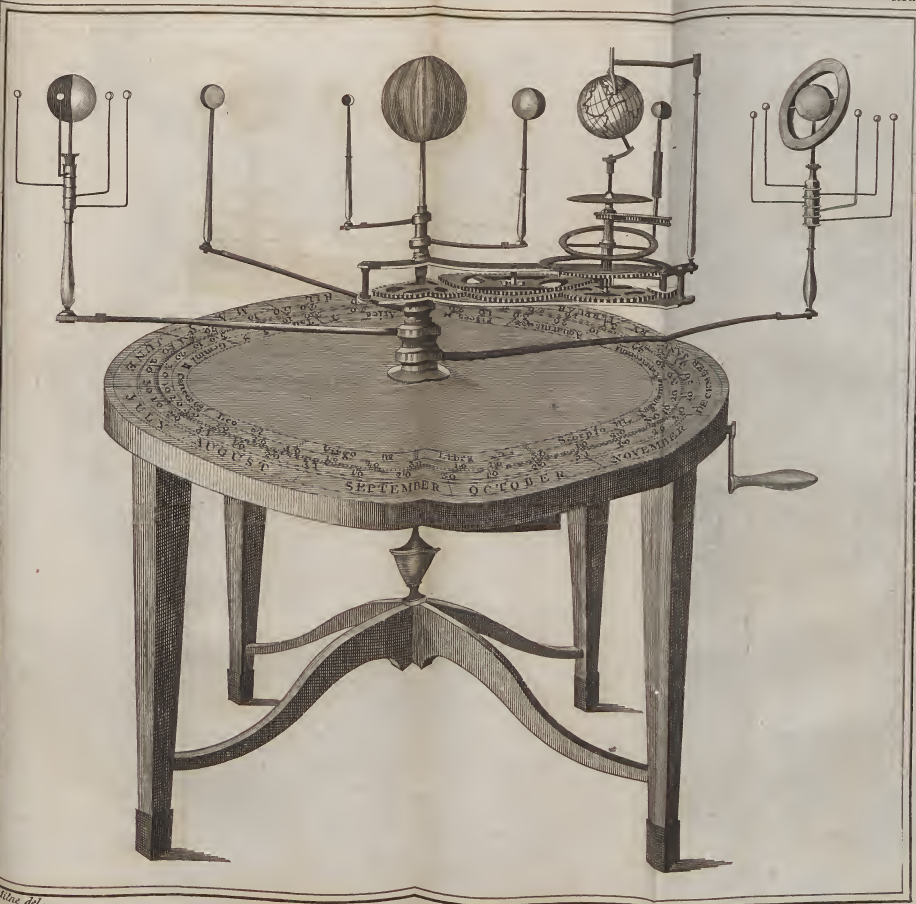

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Jn.^o Lodge sc.

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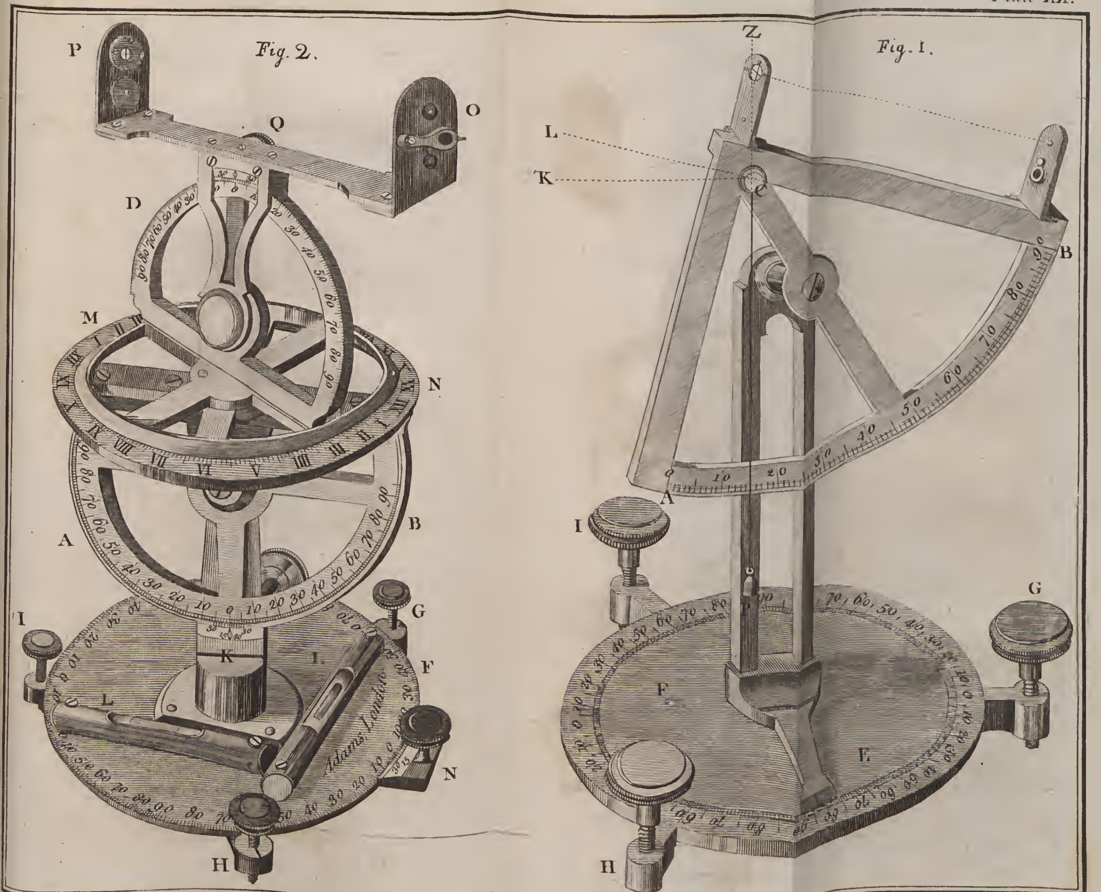
Plate XX.



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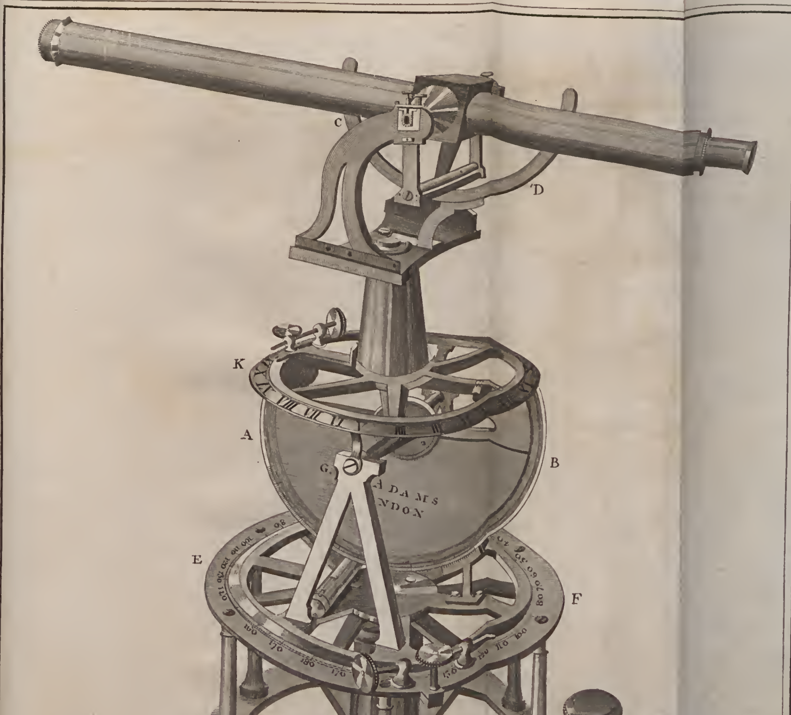
London, Publish'd Oct.r 10th 1788, by Geo. Adams, N.o 60 Fleet Street.



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J. Lodge sc.

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